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# Selenium nutrition and its impact on health

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## Introduction

Selenium is a non-metal element that occurs in the earth's crust at levels of 50-90 μg/kg with the higher levels present in some sedimentary, volcanic and carbonate rocks. Selenium itself exists in a variety of chemical forms including selenite and selenate as well as elemental selenium and it is often found associated with sulphur-containing compounds. Very small quantities of selenium are required to maintain proper health in both animals and humans and this selenium must be obtained through dietary sources. The necessity for selenium is most likely related to its presence in particular proteins termed selenoproteins. There are around 25 selenoproteins in humans and many of these are enzymes that act to protect the body against oxidative damage. Without selenium, the function of the selenium-requiring proteins can be compromised which results in the signs and symptoms of deficiency. Since the ageing process, as well as certain diseases, including cancer and cardiovascular disease, is associated with an increase in oxidative damage, maintaining adequate selenium intakes may provide some protection against these processes[1].

## Recommended dietary selenium intake and current intake levels

In the UK, the current Reference Nutrient Intake (RNI) for selenium recommended by the Committee on the Medical Aspects of Food Policy (COMA) is 1 μg selenium per kg of body weight per day which equates to 60 and 75 μg/day for females and males respectively. An increase of 15 μg/day is recommended for lactating women. The RNI values are currently based on the levels of selenium which are considered sufficient to maximise the body's activity of the selenium-requiring enzyme, glutathione peroxidase. Dietary intakes of selenium are largely determined by geochemical environment, i.e. the selenium content of the soil from which foods are derived. The dietary selenium intake of European populations has fallen around 50% over the last three decades which is most likely related to the increased use of European Union wheat for bread flour over traditional North American varieties since EU wheat produces bread with much lower selenium content[2]. In addition, the overall consumption of cereal foods, particularly bread, has also declined within the same period[3]. Current average selenium intakes within the UK and parts of the EU are higher than the threshold for deficiency diseases, but are below current dietary reference values[4,5]. For example, the average UK intake of selenium is around 29 to 39 μg/day[6] which barely meets the lower end of the reference range for adults (LRNI 40 μg/day). For comparison, average selenium intakes within the US are 71 to 152 μg/day.

## Food Sources of Selenium and their contribution to intake

Table 1 shows the level of selenium in various food groups within the UK diet and their estimated relative contribution to daily selenium intake.

**Table 1: Levels of selenium in different food products and estimated average selenium intakes in the UK**

| Food Group | Se content | Se intake |
|---|---|---|
| | *mg/kg* | *mg/person/day* |
| Bread | 0.05 | 0.006 |
| Miscellaneous cereals | 0.02 | 0.002 |
| Carcase meat | 0.08 | 0.002 |
| Offals | 0.44 | 0.000 |
| Meat products | 0.08 | 0.004 |
| Poultry | 0.14 | 0.003 |
| Fish | 0.3 | 0.004 |
| Oils & fats | <0.007 | 0.000 |

| | | |
|---|---|---|
| Eggs | 0.19 | 0.003 |
| Sugars/preserves | 0.007 | 0.001 |
| Green vegetables | 0.009 | 0.000 |
| Potatoes | 0.014 | 0.002 |
| Canned vegetables | 0.009 | 0.000 |
| Other vegetables | 0.018 | 0.001 |
| Fruit | <0.006 | 0.000 |
| Fruit products | <0.006 | 0.000 |
| Beverages | <0.003 | 0.001 |
| Milk | 0.010 | 0.002 |
| Dairy products | 0.03 | 0.002 |
| Nuts | 0.53 | 0.001 |
| *Total* | - | *0.034* |
| **Total intake (μg/day)** | | **34** |

*Source:* Expert Group on Vitamins and Minerals: Revised review of selenium. EVM/99/17 Revised Aug 2002, 1-70. 2002*. Due to the lack of reliable data on the selenium content of individual foods, selenium intake levels were estimated by analysing samples from the Total Diet Survey which is a model of the national average domestic diet in the UK. A total of 119 categories of food and drink are included in the Total Diet and these are assigned to one of twenty broad food groups which were then measured for selenium content. Average intakes of selenium were then estimated from the levels of selenium found in each food group and the population average consumption of each food group as estimated from the National Food Survey.*

The highest mean levels are found in nuts (0.53 mg/kg), offal (0.44 mg/kg), fish (0.3 mg/kg) eggs (0.19 mg/kg) and poultry (0.14 mg/kg) (Table 1) (EMV, 2002) with bread, meat products, fish, poultry and eggs contributing the most to overall selenium intake in the UK diet. Mean selenium levels in bread and miscellaneous cereals are 0.05 mg/kg and 0.02 mg/kg respectively. In the US, selenium levels in bread are higher (0.32 mg/kg in white bread and 0.44 in wheat bread[7]). This latter finding emphasises an important aspect in that the amount of selenium in food varies greatly since it depends on the local soil selenium content and composition from which the food is grown[8,9]. In addition, selenium itself can exist in a number of different chemical forms or species, and these different species can be present at different levels in different foodstuffs. Selenium species include organically bound forms such as selenomethionine, selenocysteine and Se-methyl-selenocysteine as well as inorganic forms such as selenite and selenate. For example, selenium in foods such as bread, cereals, nuts, meat, fish and other seafood is found predominantly as the amino acid derivatives, selenomethionine and selenocysteine[9]. However, in some plants, including the leaves of beets and cabbage and in onions up to 50% of selenium present may be in the form of selenate[9]. The knowledge regarding the levels and different species of selenium that are present in different foods is currently limited, particularly with respect to animal-derived foods.

**Bioavailability and Absorption of Selenium**

The bioavailability of a nutrient is typically classified as that fraction of ingested nutrient which is utilised for normal physiological functions; absorption and retention of the nutrient are taken as indirect measures of bioavailability as these are measurable. However, these measurements cannot address functional bioavailability which is most likely to be related to health. In general, the absorption of selenium from the diet is thought to be high at around ~80% although high dietary sulphur can reduce absorption probably through competition between the chemically similar sulphur and selenium species[10]. Organically bound forms of selenium have been shown to possess greater bioavailability than inorganic forms with selenite being less bioavailable than selenate. For example, selenomethionine showed 1.6 times more bioavailability and was much more effective in raising plasma selenium and glutathione peroxide activity compared to sodium selenite in Chinese subjects[11]. There is also good evidence to show that, at least with supplemental selenium forms, organic selenium species can prolong selenium status better than inorganic selenium species after supplementation has ended[12]. However, the bioavailability of other naturally occurring selenium species is less well understood.

**Selenium Deficiency**

As mentioned above, without selenium, the function of the selenium-requiring proteins in the body can be compromised resulting in the signs and symptoms of deficiency. Selenium deficiency becomes evident at intakes below 30 μg/d. In animals, deficiency produces symptoms including growth retardation and reproductive failure and dysfunction. In humans, selenium deficiency can result in Keshan disease, a juvenile cardiomyopathy apparent in the Keshan region which can have particularly low intake levels (<15 μg/d)[13]. There is also evidence for selenium deficiency being involved in impaired immune function, and increased incidence of cancer, cardiovascular and other degenerative diseases as well as overall mortality[14,15]. In China, low selenium intakes have also been reported to be associated with high incidence of hepatitis B virus infections[16].

**Biomarkers of Selenium Status**

Dietary recommendations for selenium are currently based on the level of selenium required to optimize the activity of glutathione peroxidase (GPx), a selenium-requiring enzyme involved in antioxidant defence. However, selenium status in humans is also assessed by a number of other methods. Biochemical indicators measured include both short-term, such as serum, plasma or urinary selenium concentrations, and longer-term status measurements, such as erythrocyte, hair and toenail selenium levels[17]. However, there are no accepted 'normal' reference ranges due to the variation in selenium status between countries[18]. It is recognised that more research is needed to characterise functional markers of selenium status and how they respond to different intakes and how these relate to health outcomes in order to better define optimal selenium exposure.

**Selenium Toxicity**

The human body can tolerate quite high levels of selenium without adverse effects on health. However, at high doses (>900 μg selenium/day), selenium can elicit toxic effects collectively termed selenosis, with symptoms including gastrointestinal upset, hair loss, nausea, irritability, fatigue and mild nerve damage[19]. While high intake levels of selenium are usually difficult to ingest from food sources alone, selenosis has been observed in certain regions of China where high local soil selenium levels were associated with daily selenium intakes of up to 5000 μg/day. In these cases, subjects recovered from their symptoms after evacuation from the area and the consequent change in diet. Many animal studies have also shown that the inorganic selenium species show more toxicity than organic forms, with selenite being the most toxic[20].

**Optimising Food Sources of Selenium**

Currently, selenium intakes within the UK are lower than recommended therefore a case for increasing the selenium levels within the population may be made. Presently, the level of selenium permitted in feeds of all classes of domestic livestock are strictly controlled and are limited to 0.5 mg selenium/kg within the EU and to 0.3 mg/kg within the US, irrespective of selenium form. On the whole however, many UK manufactured feeds and mineral mixes contain selenium, almost invariably as the inorganic form sodium selenite, at a concentration of 0.3 mg/kg. It has been estimated that by increasing the selenium level to 0.5 mg/kg and by replacing inorganic forms of selenium with organically bound forms could boost selenium intakes by around 50%[21]. In addition, increasing the currently permitted levels of selenium in feeds and mineral mixes by two-fold would in itself probably be adequate to deal with the current shortfall in selenium intakes in the UK[21]. Conversely, a number of other strategies could also be employed to enhance the population selenium status including the application of more selenium-enriched fertilisers to soils for increasing selenium in subsequent crop and animal products, direct fortification or enrichment of food products with selenium forms, or potentially through the use of selenium supplements. Additionally, increases in selenium intake could also be achieved through food product reformulation through enhanced selection of ingredients to maximise the selenium content.

**Perspective**

The selenium status of the UK population is below currently accepted levels. In addition, due to the increasing interest in public procurement and consumption of more locally produced foodstuffs within the UK, the selenium status of the population may be reduced further due to the inherent low selenium content in UK soils. The shortfall in the UK selenium status could be addressed through a number of different approaches. However, it is clear that more research is also required to establish how different functional markers of selenium status respond to different intakes of different forms of selenium and how these relate to promoting health and ameliorating different diseases before clear decisions can be made regarding the best strategy to address the shortfall.

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