SELENIUM IN FOOD AND FOOD SUPPLEMENTS

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Abstract
The bioelements detected in the lithosphere and biosphere have aroused major interest in geology and biology. It was detected in minerals but also in tissues taken from plants, animals and humans. Among the bioelements, the natural distribution of selenium (Se) was studied, following the quantity in food, the structural specificity of the components. Along with these, the biological activity was studied, following its integration in food supplements.

Key words: selenium in environment and foodstuffs; structure-activity relationship

Introduction

Selenium is a trace element occuring in all cells of the organism. Its quantity varies from tissue to tissue being dependent on the nutritional intake conditioned by the geographical environment (soil, water). Selenium can be found in higher concentrations in thyroid, kidneys, testicles, liver, etc.

It was identified in 1817 by Berzelius and considered long time as toxic. Only in 1957 was it recognized as an important micronutrient for the organisms.

1. Structural forms of selenium in the environment

In the environment, selenium is found in soils both in inorganic and organic forms. The oxidation states of selenium compounds range from -2 to +6. Its geographical distribution varies greatly, the amount of selenium in soil being between 0.01 - 2 mg/kg.

The inorganic form of Se in soil are: selenate (SeO_4^{2-}) - a compound with good water solubility and bioavailability; selenite (SeO_3^{2-}) – having a water solubility and bioavailability below that of selenate. Also, elemental selenium (Se^0) or selenides (Se^{2-}) can also be found in soils - these being insoluble forms of selenium. The organic forms of selenium found in soil include methylated or unmethylated selenium amino acids, dimethyl selenide, dimethyl diselenide, selenomethionine; selenocysteine [1, 2, 3].

In drinking water selenium can come from discharges from mines, natural deposits, dischage from refineries, or from agricultural activities. Also, selenium is found in foods of plant and animal origin [4, 5].
The selenium compounds found in foods are the amino acid derivatives selenomethionine, Se-methylselenocysteine, selenocysteine. The inorganic forms selenite and selenate are found in smaller amounts (fig.1).

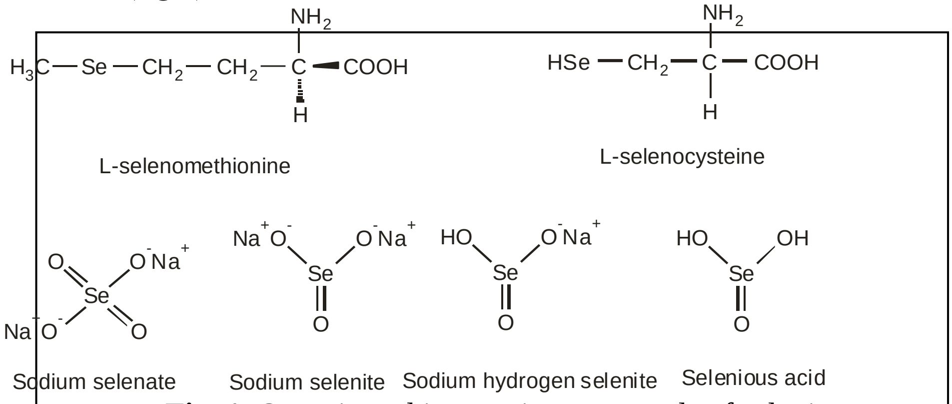

Fig. 1. Organic and inorganic compounds of selenium

There are 25 selenoproteins identified until now in humans. The exact role is not known for about half of the selenoproteins. The amount of selenium found in blood and tissue is related to dietary intake [5, 6, 7].

2. Biological activity

The biological role of selenium was unknown until the middle of the twentieth century, when Schwarz and Foltz [6] showed that necrotic liver degeneration can be caused by selenium deficiency. Later, in 1973 selenium was found in the composition of mammalian enzymes, such as glutathione peroxidase [7]. In the intervening years, the essential characteristic of selenium for human nutrition was established.
Regarding the biological role of selenium, one can mention the fact that it is part of the endogenous antioxidant defence system. The function of this system is to protect cells against the attack of reactive oxygen species [8]. Selenium also plays a role in normal spermatogenesis, the maintenance of normal hair and nails, normal function of the immune system and normal thyroid function [9, 10].
Selenium is found in the structure of the enzyme glutathione peroxidase (that acts as a scavenger of hydroperoxides, phospholipid hydroxiperoxides), selenoproteins, some amino acids and 5'-deiodinase (involved in thyroid metabolism). The absorption of selenomethionine takes place in the small intestine by a carrier-mediated process.
Absorption of selenium can be studied by using the activity of the enzyme glutathione peroxidise since this enzyme contains selenium-amino acid residues. Using this method, the relative bioavailability of selenium from different food sources can be evaluated. Labelled selenium (^{75}Se) can also be used in the study of absorption.
Plasma biomarkers like selenium concentration and selenoprotein concentration were also used to evaluate the bioavailability of various forms of selenium. The plasma selenium concentration was raised in a dose-dependent manner by L-selenomethionine and high-selenium-enriched yeast.
After absorption, L-selenomethionine is metabolised to hydrogen selenide (H_2Se) via selenocysteine or methylselenol. This process can be followed by conversion to selenophoshate ($HSePO_3$), which is then incorporated into essential selenoproteins. The surplus of hydrogen selenide is further metabolised. The resulting compounds, methylated derivatives or

selenosugars are excreted in urine. They can also be oxidised to selenium dioxide, a pathway associated with toxicity due to the production of reactive oxygen species.
Selenium from selenite - following oral intake and absorption - is found in the highest concentrations in the liver and kidneys. After absorption, selenium is converted to hydrogen selenide (H_2Se). From this point on, the same reactions take place as in the case of L-selenomethionine [11].

3. Distribution in foods and requirement

Given the importance of selenium for the normal function of the human body various sources have been devised of assuring its optimum intake.

3.1. Vegetal and animal sources

The main vegetal sources of selenium are cereals and vegetables. The amount of Se in such products varies conditioned by the soil content in selenium, therefore by the geochemical characteristics. Depending on their ability to assimilate and accumulate, plants can be classified into "selenium accumulators", e.g. rapeseed, broccoli, cabbage, garlic, onions, leeks and "non-selenium accumulators", e.g. wheat, oats, rye, barley (Table 1).

Table 1. Selenium content in plant foods (mcg per 100 g edible parts)

Specification	Content (mcg / 100 g)	Specification	Content (mcg / 100 g)
Brazil nuts	230	Pistachio	6,8
Sesame seeds	56	Graham bread	3,1
Peanuts	30	Peanut butter	3,0
Cashew nuts	15	Barley	2,8
White rice	13	Almonds	2,2

Food products of animal origin containing higher amounts of selenium are meat and viscera (liver, kidneys), fish, eggs, dairy products, etc. (Table 2). The amount of selenium in these products is closely related to animal feed.

Table 2. Selenium content in food of animal origin (mcg per 100 g)

Specification	Content (mcg / 100 g)	Specification	Content (mcg / 100 g)
Chicken	28	Salami	13
Porc	17	Pike	24
Beef	9	Egg yolk	59
Lamb	7	Egg white	8
Raw ham	15	Whole milk UHT	1,1

3.2. Nutritional requirements

Expressed in mcg / day, it differs depending on age, physiological condition and are: for children: aged 7-11 months 15; 1-3 yrs 15; 4-6 yrs 20; 7-10 yrs 35; 11-14 yrs 55; 15-17 yrs 70 and for adults: ≥18 yrs 70; Pregnant females - 70; Lactating females - 85.
Selenium requirements in humans is assured mainly by various foods of vegetal and animal origin. An other convenient way of ensuring an optimum selenium intake is represented by fortified foods or food supplements (concentrated sources of nutrients).

4. Food supplements with selenium

Currently, in the European Union, six forms of selenium can be used, i.e. selenium enriched yeast, selenomethionine and selenious acid, sodium selenate, sodium hydrogen, selenite sodium selenite while in fortified foods only four forms are admitted [12].

The evaluation of the various chemical forms of selenium was carried out by the European Food Safety Authority (EFSA), prior to their inclusion in the lists of admitted chemical forms.

a) Chemical compounds accepted in food supplements

In food supplements L-selenomethionine and selenious acid are the mostly used chemical forms. L-selenomethionine is a selenium containing amino acid in which selenium replaces the sulphur atom found in methionine [13].

The bioavailability of selenium from L-selenomethionine was shown to be higher than that from inorganic compounds of selenium. It is estimated to be greater than 90%.
Regarding the bioavailability of selenious acid, it can be considered equivalent to that of sodium selenite, since both of them dissociate to their component ions in the gastrointestinal tract.

b) Nutritional Reference Value

In the EU Regulation no. 1169 / 2011 - Annex XIII - the amount of 55 mcg per day was established as the Nutritional Reference Value (NRV) for selenium. A physiological effect is considered to be achieved when Se content is at least 15% of NRV.

5. Deficiency and excess

Deficiency of Se was observed in patients with selenium-free parenteral nutriton. In their cases symptoms of skeletal myopathy, muscle weakness a.o. were detected. A diet low in iodine and selenium is thought to be a risk factor for myxomatosis, too. It has also been found that selenium deficiency may be involved in organ and tissue degeneration with the onset of Keshan disease (endemic cardiomyopathy) and / or Kashin-Beck disease (chronic degenerative osteochondropathy).
Excess of Se - when the intake exceeds 1000 mcg/day - can lead to the appearance of selenosis. It is manifested by headache, thinning hair, nail deformation, rash, large number of tooth decay with discoloration of the teeth, paresthesias, paralysis and hemiplegia. In high doses, selenium itself has been shown to be carcinogenic.

Concluding remarks

Selenium is a trace element that can be found in lithosphere and hydrosphere and is an essential nutrient for humans in small amounts. It is present in various quantities in foodstuffs of vegetal and animal origin. In food supplements six selenium compounds are admitted as ingredients. Also, a number of four selenium compounds can be used to fortify various foods.

The current paper reviews information regarding the inorganic and organic compounds of selenium used in food supplements. It is also discussed the biological activity of selenium, its nutritional reference value in humans, its bioavailability, effects of Se deficiency and excess.

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