Biomedicine & Preventive Nutrition 4 (2014) 333–341

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Review

Selenium nutrition: How important is it?

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ARTICLE INFO

Article history:
Received 18 December 2013
Accepted 1st January 2014

Keywords:
Selenium
Dietary requirement
Selenoprotein
Selenium deficiency

ABSTRACT

Selenium is an essential trace element and integral part of many antioxidant enzymes such as glutathione peroxidase and selenoprotein P in humans and animals. Deficiency of selenium leads to various clinical consequences including cancer, cardiovascular diseases, type 2 diabetes and lung disorders. This review gives a brief outline of the current information on selenium in the environment, its natural sources, dietary requirement, various selenoproteins, the role of selenium as an antioxidant in defense systems, as well as its antimicrobial and radioprotective abilities. The relationship between selenium deficiency and various health outcomes, in particularly cardiovascular disease, nervous and gastrointestinal abnormalities dysfunction of the thyroid and immune systems type 2 diabetes and fertility, are also reviewed. The exact chemical form and dose, which results in the normal functioning of numerous body systems or risk of disease are intricate but need to be elucidated through good clinical practice for efficient public health strategies.

1. Introduction

Selenium (Se), a non-metal, the 34th element in the periodic table was misidentified as tellurium by MH Klaproth initially and later in 1818, Swedish chemist JJ Berzelius discovered selenium [1,2]. He named it selenium from Selene, the Greek goddess for Moon [2]. This trace element is present in the earth's crust at an average of 90 μg/kg and levels are more in carbonate rocks, volcanic and sedimentary soils (global average 0.4 mg/kg), which may subsequently then accumulate in various plants [3]. The properties of selenium lie between adjacent sulphur and tellurium and it exists in 4 oxidation states (−2, +1, +2 and +6) with chemical forms of selenide, selenite, selenate, etc. and is often associated with sulphur containing compounds [3,4]. Schwarz and Foltz established the nutritional value of selenium in 1957 [5].

2. Sources, requirement, metabolism and distribution of selenium compounds

Selenium exists predominantly in plants and meat in both inorganic forms such as selenite, selenate, selenide and in organic forms like selenomethionine, methylselenocystine and selenocysteine [6–8]. Sea food and organ meats are the richest source of selenium [7,8]. Muscle meat, cereals, grains, egg, vegetables and dairy products are other sources of selenium [9]. Even though Brazil nuts are the richest source of selenium [10], it is neither readily available nor all commonly eaten. Selenium exists in various chemical forms in different food stuffs such as selenate in water, fish and cabbage [7,8], Se-methylselenocysteine in garlic, onions and broccoli, selenomethionine in plant sources, yeast, selenocysteine in animal foods and meats and selenoneine, a recently discovered selenium compound found in chicken, tuna and mackerel [8,11]. Various sources and levels of selenium are depicted in Fig. 1, however the quantities may vary widely according to the soil content of selenium in different continents [12].

Intake recommendations for selenium and other nutrients are given in the dietary reference intake (DRI) developed by the Food and Nutrition Board (FNB) of the Institute of Medicine of the National Academies [13]. Recommended dietary allowance (RDA) of selenium for infants, children and adults are enlisted in Table 1 [13]. High intake of organic/inorganic selenium causes selenosis, resulting in hair loss, nail loss, brittleness, lesions in the skin and nervous system, fatigue and irritability [14,15]. Acute selenium toxicity causes severe neuronal lesions, gastrointestinal symptoms, respiratory symptoms, kidney failure, myocardial infarction and other cardiac disorders [15]. Upper levels of tolerable intake established by FNB [13,16] are also given in Table 1.

The absorption of selenium compounds varies according to their chemical form, 90% in case of selenomethionine while that of selenite is 80%. Selenium is mainly absorbed in the duodenum by enterocytes through aminoacid transport systems and catabolised into elemental selenium that gets incorporated into glutathione peroxidase (GPx) [7,15,17]. These selenoproteins are transported into the liver, where they are converted into selenoprotein P (SePP)

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2210-5239/$ – see front matter
http://dx.doi.org/10.1016/j.bionut.2014.01.006

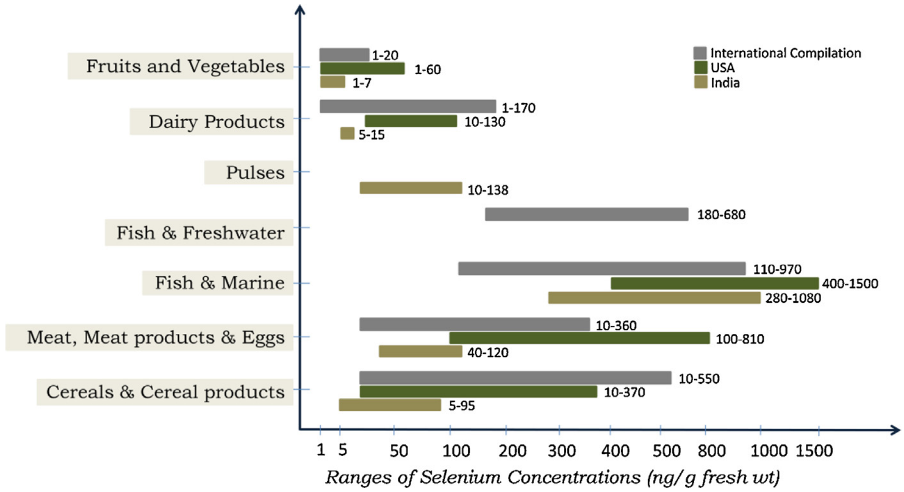

Fig. 1. Various sources and levels of selenium.

and distributed to various organs [17] like brain, kidney, heart, spleen, muscles and gonads (Fig. 2).

3. Why selenium is important?

Very small quantities of selenium are required through dietary sources to maintain good health in both animals and humans. In humans, the nutritional function of selenium is achieved by selenocysteine containing 25 proteins termed selenoproteins (SeP); different types of SeP, tissue distribution and health effects/functions are enlisted in Table 2.

4. Health effects of selenium

4.1. Selenium: antioxidant activity

SeP are having many roles in the body, perhaps the most important is that of an antioxidant, by protecting the body against oxidative damage [18–20]. In normal condition, the free radical productions are essential and they are neutralized by the presence of adequate amount of antioxidants (Fig. 3A).

Extensive oxidation enhances the production of highly unstable compounds known as free radicals, which leads to oxidative stress [21] (Fig. 3B), and if they are not destroyed, will damage the biological components in the body causing lipid peroxidation, protein carbonylation and DNA strand breakages, ultimately leading to various clinical consequences [22], (Fig. 4).

Living cells are equipped with a self-defense system to protect from the oxidative stress through the antioxidant mechanisms. There are two types of antioxidants, internal and supplementing antioxidants. Internal antioxidants such as SOD and GPx are enzymes, which are synthesized in the cells and act as primary defense system against free radicals [23], whereas supplementing antioxidants like vitamins and selenium are secondary defense system against radicals (Fig. 5). GPx and other selenium containing enzymes are the major selenium containing internal antioxidants help in the neutralization of highly reactive free radicals [24]. GPx converts reduced glutathione to oxidized glutathione while reducing peroxides by converting them to harmless alcohols thus maintaining the membrane integrity [24,25]. Redox potential of the selenium compounds give important information on deciding the antioxidant activity [26]. Priyadarsini et al. gathered the information on redox potential of various selenium compounds and their antioxidant activities [26]. Deficiency of selenium ultimately leads to deficiency of selenium containing internal antioxidants which may cause clinical morbidities.

5. Selenium and cardiovascular diseases

Some studies have suggested that supplementation of selenium could reduce the risks associated with cardiovascular diseases as selenium prevents the oxidative modification of lipids, platelet aggregation and inflammations [27–32]. Low levels of plasma selenium is associated with the increased risk of cardiovascular disease mortality [33]. Heart disease mortality declined to 55% in men and 68% in women in Finland due to the increase in dietary selenium intake [34].

Free radicals produced in the body are highly toxic to the myocardium causing excessive necrosis, myocytolysis and edema [35]. Concrete evidence exists for the antithrombotic effect of selenium through the interaction between platelets and endothelial cells via GPx [27,36]. Selenium associated with GPx4 reduces phospholipid hydro peroxides which in turn reduce the accumulation of oxidized LDL in arterial wall which may reduce the platelet

Table 1
Recommended dietary allowance and tolerable upper intake of selenium.

Age	Recommended dietary allowance			Tolerable upper intake levels (μg/day)
	Males & females (μg/day)	Pregnancy (μg/day)	Lactation (μg/day)	
0–6 months	15	NA	NA	45
7–12 months	20	NA	NA	60
1–3 years	20	NA	NA	90
4–8 years	30	NA	NA	150
9–13 years	40	NA	NA	280
14–18 years	55	60	70	400
>19 years	55	60	70	400

NA: not applicable.