Ecotoxicology and Environmental Safety 149 (2018) 291–306

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Review

Developmental selenium exposure and health risk in daily foodstuffs: A systematic review and meta-analysis

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ARTICLE INFO

Keywords:
Selenium
Dietary intake
Selenoprotein
Bioavailability
Antioxidant

ABSTRACT

Selenium (Se) is a trace mineral and an essential nutrient of vital importance to human health in trace amounts. It acts as an antioxidant in both humans and animals, immunomodulator and also involved in the control of specific endocrine pathways. The aim of this work is to provide a brief knowledge on selenium content in daily used various foodstuffs, nutritional requirement and its various health consequences. In general, fruits and vegetables contain low content of selenium, with some exceptions. Selenium level in meat, eggs, poultry and seafood is usually high. For most countries, cereals, legumes, and derivatives are the major donors to the dietary selenium intake. Low level of selenium has been related with higher mortality risk, dysfunction of an immune system, and mental failure. Selenium supplementation or higher selenium content has antiviral outcomes and is necessary for effective reproduction of male and female, also decreases the threat of chronic disease (autoimmune thyroid). Generally, some advantages of higher content of selenium have been shown in various potential studies regarding lung, colorectal, prostate and bladder cancers risk, nevertheless results depicted from different trials have been diverse, which perhaps indicates the evidence that supplementation will merely grant advantage if the intakes of a nutrient is deficient. In conclusion, the over-all people should be advised against the usage of Se supplements for prevention of cardiovascular, hepatopathies, or cancer diseases, as advantages of Se supplements are still ambiguous, and their haphazard usage could result in an increased Se toxicity risk. The associations among Se intake/status and health, or disease risk, are complicated and need exposition to notify medical practice, to improve dietary recommendations, and to develop adequate communal health guidelines.

1. Introduction

Selenium [Se] is a trace mineral and an indispensable micronutrient for all humans. Diet is the most important source of this trace mineral to all living organism. The intake of Se mainly depends on its food contents and the total amount of food consumption. The biochemical nature plays an important role in its bioavailability, which is being found considerably higher for organic chemical forms (Dumont et al., 2006; Sigrist et al., 2012). Increased Se emissions and other trace elements has produced a thorough counterpunch for both the environment as well as human health (Ullah et al., 2017; Yousaf et al., 2017a, 2017b). The role of Se in human health is antioxidant, as it shows a kind of enzymatic redox action by means of vital enzymes named glutathione peroxidase. Glutathione peroxidase enzyme and vitamin E, both collectively activates the process of hydrogen peroxide reduction and further by virtue of cell protecting practices reduces hydro peroxides from oxidative deterioration. Moreover, the role of Se is crucial in many metabolic processes and also among endocrine and immune systems (Williams and Harrison, 2010; Sigrist et al., 2012). The intake of Se become toxic when taken at high levels and can cause poisoning in human beings and animals (Al-Ahmary, 2009). For the production of selenoproteins, Se is assimilated into proteins. The oxidative pressure is protected by a number of selenoproteins (Al-Ahmary, 2009).

Deficiency of Se can cause cancer, some cardiovascular diseases (Foster and Sumar, 1997) destabilized immune scheme and hypothyroidism (Ellis and Salt, 2003). Kashin-Beck and Keshan disease found mostly in China and in some regions of Asia, where very low levels of Se were found (Reilly, 2006; Saxena and Jaiswal, 2007). High contents of

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https://doi.org/10.1016/j.ecoenv.2017.11.056
Received 31 August 2017; Received in revised form 19 November 2017; Accepted 22 November 2017
0147-6513/

Se has toxic and harmful effects (Reilly, 2006; Pappa et al., 2006). Chronic selenosis happened in several regions of the world due to the presence of extremely high levels of Se in soils, which has resulted in different disorders such as, nail brittleness, hair loss, gastrointestinal dysfunctions, skin rash, "garlic-breath" smell and neurological disorder (Yang and Zhou, 1994; Reilly, 2006; Al-Ahmary, 2009). Severe intoxication can cause critical tubular necrosis and gastric ulcer or acute gastritis, mainly relying on the intake amount (Kise et al., 2004; Kample et al., 2009). Both excessive and deficient ingestion of Se has malignant effects on the organism. The gap among high and low undesirable intakes is very narrow, presenting unpredictable situation for optimal intake of Se, which requires a comprehensive information to be known (Rayman, 2008). Therefore, it is of great importance in recent days to know the Se deficiency and abundance in different foodstuffs in order to estimate its real intakes of people.

Globally, about 15% people of the total estimated 7000 million population, are selenium-deficient (White et al., 2012). Some of the Se-deficient reported areas in the world are China, Russia, Poland, and some volcanic areas of previous Yugoslavia country. Various research studies have concluded a protective effect of Se in resistance against some kinds of cancer disease (Brozmanová et al., 2010), controls molecules released by immune cells during respiratory disorder (asthma) and also reduce heart disease casualty (Brown and Arthur, 2007). It also strengthens the bone balance and acts as guard against bone injury and damage (Zhang et al., 2014). Se-deficient soils in many geographic areas are considered to cause bone disorders and cardiovascular diseases, which may be sorted out by ingestion of food Se (Lemly, 1997; Tan et al., 2016).

The status of Se in food is generally reflected by its availability and contents in the soils of a region, where it is produced. Globally, an extensive variations exists in the soils Se content (Cuvardic, 2003). High contents of Se (> 5 mg/kg) in soils were calculated in countries like Canada, Germany, France and some areas of western USA, whereas, very low Se levels (< 0.05 mg/kg) were found in soils from some regions of China, New Zealand and Finland. Therefore, the concentration of Se is variable among the same foodstuff, depending mostly on cultivated arena of producing or cultivating. Hence for this reason, the local or regional information for nutrients can imitate this type of variations and may be more applicable than those who account the data related to average dietary intake (Smrkolj et al., 2005; Fordyce, 2005; Tan et al., 2016). However, insufficient or even no data about the Se concentration in food and soils is still an issue of great concern in several regions of Southern Asia, Africa and South America, (Samman and Portela, 2010; Sigrist et al., 2012). Many authors described some schemes, through which we can improve Se contents in food of the people living in areas of Se-deficient soils which are, (i) application of Se- enriched fertilizers (Dumont et al., 2006), (ii) augmentation/supplementation of Se to the field or farmland animal food (Tinggi, 2003; Muniz-Naveiro et al., 2006; Pappa et al., 2006; Lyons et al., 2007) and (iii) the undeviating or direct intakes of Se food additions (Dumont et al., 2006). Nevertheless, the people should be advised regarding the Se intakes additions aimed for diseases control, because advantages of Se supplementations are still ambiguous and their haphazard application might produce some risks of increased Se toxicity (Stoedter et al., 2010).

For humans, the food Se intake mainly depends on its contents present in foodstuff and quantity of food utilized (Reilly, 2006; Al-Ahmary, 2009; Slencu et al., 2012). The concentration of Se in different foodstuffs significantly varies depending mainly on level of the element exist in the soil, where growth of the plant species or animals takes place (Barclay et al., 1995; IOM, 1998; Uden et al., 2004). Humans get Se mainly through the dietary intakes/food ingestion. Specifically, seafood and meat are considered the key sources for Se, as most of the animals need Se, while in case of plants, not as necessary as animals (Sirichakwal et al., 2005; Klapec et al., 2004). Globally, the ingestion of dietary Se differs significantly among people due to the presence of huge variation in the Se levels of foodstuffs in different regions (McNaughton and Marks, 2002). For that reason, in every country of the world, the monitoring of Se concentration in typical and most extensively used food is indispensable and important.

The physicochemical properties of Se is highly similar to sulfur, hence replace it in the amino acids, therefore high Se contents are found in protein-rich foods, e.g. meat, eggs, fish, chicken, and cereals, particularly in the form of organic mixtures (Sager, 2006; Klapec et al., 2004; Ventura et al., 2007a, 2007b). The role of these food groups for dietary Se intake is most important. Fish is reported to be the highest in foodstuff list in terms of Se content, with huge fluctuation among its diverse classes. Nevertheless, fish is typically considered a deprived home of available Se, due to the presence of undue contents of heavy metals and Hg element, fix to Se developing inorganic compounds, which are insoluble. By this way, the toxic effects of many trace elements and metals are reduced by Se (Pappa et al., 2006). Some sulfur compounds-enriched vegetables like broccoli, cauliflowers, cabbage, Brussel sprouts, garlic, onion and chives could be converted into a decent nutritional source of selenium relying on its consumed amount. Vegetables and fruits generally contains low Se contents with a value of about 10–20 µg/kg, most probably because of small amount of protein (Klapec et al., 2004; Ventura et al., 2009; Sigrist et al., 2012), thus, their contribution to the Se dietary intake is very small. Among the foodstuffs, the highest levels of Se were reported to be 3800 µg/kg, in Brazilian nuts (Manjusha et al., 2007). The significant addition of cow's milk to that of total dietary intake, largely for children is of great concern (Zand et al., 2011; Pappa et al., 2006).

It is absolutely significant to perform an accurate calculation of content of Se in various foodstuffs since the gap among the low and high levels is quite narrowing for safety. The currently available different procedures for the analysis of trace element selenium (Foster and Sumar, 1995) are, (i) analysis of neutron mobilization (Slejkovec et al., 2000), (ii) AFS (atomic fluorescence spectrometry) (Semenova et al., 2003; Pappa et al., 2006), (iii) AAS (atomic absorption spectrometry) by means of both electro-thermal reduction to atoms/atomization (Hussein and Bruggeman, 1999) and method for production of hydride (Mindak and Dolan, 1999), and (iv) ICP MS, or inductively coupled plasma spectrometry (Park and Kim, 2001; Featherstone et al., 2004).

2. Selenium content in different foods

Food safety for public health has prime importance worldwide and oral ingestion of food has been reflected as a most significant exposure path of selenium and other PTEs to humans. Human diet may contain a range of essential as well as toxic elements (Abbas et al., 2017). Most of the people get the total Se nearly from the foods which they consume. In plant and animal tissue, Se is located usually bound with proteins. Hence, the utmost important food sources of Se reported are seafood and meats (based on their higher protein contents), and cereals, as they likely to be taken in massive amounts (Fig. 1). On contrary, foods with comparatively low protein contents, such as fruits and vegetables, have relatively low contents of Se. In all cases, food Se contents reveals the available soil Se content utilized for the production of these foods (Lichtfouse et al., 2015). Different sources and ranges of selenium concentration are depicted in Fig. 2, still the amounts may differ extensively according to the soil Se content in different regions (Mahalingam et al., 1997).

The Upper Level (UL) of tolerable intake for an adult is fixed at 400 µg/day, which is built on an adverse effect known as selenosis (Food and Nutrition Board, USA Institute of Medicine, 2000). For adults a so-called population reference Intake of 55 µg Se/day, however based on other criteria more levels of intakes were also set by the Scientific Committee for Food of the European Commission (1993). A combined IAEA /FAO /WHO skilled discussion (WHO, 2004) provided numerous ways for the requirements calculation of an individual and entire populations. The daily Se dose set by World health organization, for an