SELENIUM CONTENTS IN WHEAT

Lateffa BABA AHMED[a,*], Brahim BELADEL[b], Samiha BENAROUS[a]

[a]Laboratory of fundamental and applied physics, University of Blida1 PB 270 Blida, Algeria
[b]Faculty of Sciences Ziane Achour University PB 3117 Djelfa, Algeria
[*]Corresponding Author Email : rlatefa@gmail.com

ABSTRACT

Up to date research studies show that Selenium is a major key player in many physiopathology cases. Selenium is antioxidant acting at the biological cell Cytosol. Its action is supplemented by vitamins A and E act synergistically in the membranes of biological cells.A moderate deficiency on Selenium intake, and in particulate, in the case of a low level in vitamin E, appears to increase the sensibility to some diseases where the antioxidant property is involved such as: Cardiovascular diseases, inflammatory diseases, viral infections, diseases neurodegenerative and cancer. Such findings were the stimulus to in-depth investigations of the regional relevance of Selenium in human nutrition. During the last 20 years researchers, in different countries, were interested in Selenium concentration of frequently consumed food especially in wheat. Consequently, Selenium concentrations in plants reflect generally the concentration of Selenium in soils.

KEY WORDS

- Selenium,
- wheat,
- daily intake,
- glutathione,
- keshan disease,
- kashin-beck.

LISTE OF ABBREVIATIONS

ADI	Acceptable Daily Intake
AIDS	Acquired Immune Deficiency Syndrome
FAO	Food and Agriculture Organization of the United Nations
HAART	Highly Active Antiretroviral Therapy
HIV	Human Immuno Deficiency Virus
INAA	Instrumental Neutron Activation Analysis.
PLHIV	People Living With HIV
Redox	Reduction-Oxidation
RNI	Recommended Nutrient Intakes
TE	Trace Elements
WHO	World Health Organization

KEY FACTS

1. Selenium is an essential element for humans as constituent of selenoproteins that play critical roles in reproduction and health.
2. Selenium deficiency can lead to Keshan and /or Kashin-Beck diseases.
3. Plantsplay an importantroletoconvertinginorganic formsof selenium to those organic.
4. Recommended selenium intake for adults is 55 µg/day.
5. Continuous supplementation should be considered for countries withlow seleniumsoils.

SUMMARY POINTS

- This paper focuses on Selenium concentration in wheat.
- Selenium is a major key player in many physiopathology cases.
- Selenium concentrations in plants reflect generally the concentration of Selenium in soils.
- Wheat is a vital crop in transport of selenium from Soil to human.
- Both excess and deficiency of selenium may disturb normal biochemical functions of the body.
- Selenium has a great role in the metabolism, is essential in male fertility by participating in the synthesis of the progesterone and spermatogenesis.
- Selenium deficiency leads to muscular dystrophy, bone or embryonic deformities.

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INTRODUCTION

The micronutrients or Trace Elements (TE) are present in all living organisms and belong to the periodic table of elements. These TE have common characteristics to be metal or metalloid and meet specific criteria. Their presence in human organism is important at very small quantities. Among the 17 identified TE in mammals, 12 are be considered essential[1]. They are biological catalysts, used for the appropriate functioning of the protein, enzymatic and genetic systems.Human growth metabolism depends on a balanced diet containing protein, lipids, and carbohydrates. It also relies on the supply of optimum quantities of inorganic micronutrients. These micronutrients constitute a small fraction of the entire diet but play important roles in different metabolic processes. Their excess or deficiency may disturb normal biochemical functions of the body[2,3,4].

Hence, Selenium is a key compound for the well-being and is insufficiency has to be avoided. Endemic deficiencies can occur when soils are low in Selenium content[5].

The Chinese province of Keshan is historically the origin of the discovery of the essential property of this mineral: this region soils are poor on Selenium content and has caused in the population some endemic fatal cardiomyopathy disease[6,7,8].

There is interest to consume whole gross meal products, refined processed food result in a significant loss of Selenium,almost 60%, as well as other minerals losses[9,10].

Garlic,whichis often citedas a good source, is actuallyrich in Selenium(10 to 20 µg per 100 g), however it is uncommon to consume several hundred grams per day[11].

Consequently, it is a necessity to find a food which can provide good daily intake of Selenium.It has been demonstrated that the activity of the enzyme decreases markedly in response to dietary deficiency[12,13]. Some trace elements, e.g. Cr, Mo and Zn, are essential for plant growth and human and animal nutrition but can create toxicity when accumulated in excessive concentrations in soil and plants. Other trace elements such as Cd, As, Hg and Pb, not essential for either plants or humans and animals, pose risks when they enter the food chain. Although contaminants in food and fodder do not induce quick death, they cause chronic health effects[14].

Therefore, the ability of contaminants to release trace elements should be properly regulated through agronomic, biochemical and physical processes and decontamination programs[1.15-17].

During the last decades, the increasing demand of food safety has stimulated research regarding the risk associated with consumption of food stuffs contaminated by pesticides, heavy metals and/or toxins[18,19,20].Some native plants such as Astragalus, Xylorhiza, and Stanleya, are able to accumulate high internal concentrations of Selenium more than 1000 mg/kg, they require the Selenium for their growth and they grow only in high Selenium concentration soils[21].Similar foods may have very different concentrations of Selenium depending on the origin of the agricultural product. Thus, because similar foods may be grown in several locations, use of single database Selenium concentrations may lead to erroneous conclusions[5.22].

1- PHYSICOCHEMICAL PROPERTIES OF SELENIUM

Selenium is the only non-metal that is not a biologic component material (carbon, nitrogen, oxygen, sulfur, phosphorus). Selenium has great chemical similarities with the sulphur r S) : the ion radius (S = 0.37Å, Se = 0.5Å), the bond length and energy of S-Sand Se-Se as well as the potential ionization23are also similar. Those similarities contribute to explain some substitutions of Selenium by Sulfur in sulfide minerals, such as pyrite, and in many other organic molecules, such as the amino-acids Methionine or Cysteine[24].

Selenium is present in nature under04oxidation states: Selenate (Se + VI), Selenite (Se + IV), elemental Selenium (SeO) and Selenide (Se-II). Selenate $(SeO_4)^{2-}$and Selenite $(SeO_3)^{2-}$ areoxidizedinorganic soluble mobile forms that are widely find in soils, sediments and water[25-30,46].

	Oxydation State	Name	Formulas	Comments
Inorganic	Se (+VI)	Selenate	$H_2SeO_4/HSeO_4^-/SeO_4$	Most mobile form, common in soils, water and sediment, easily bioavailable to plants.
	Se (+IV)	Selenite	$H_2SeO_3/HSeO_3^-/SeO_3$	Soluble form, common in soils, easily absorbed on solid particles.
		Selenium dioxide	SeO_2	Gas generated by volcanic and combustion of fossil fuel dissolved in water in the form of $H_2SeO_3^-$.
	Se (0)	Elementary Selenium	Se^0	Insoluble form stable in redox environments.
	Se (−II)	Seleniure	Se^{2-}	Motionless form, substituted sulfur in minerals.
		Hydrogen Seleniure	H_2Se	Gas produced by volcanism, the combustion of fossil fuel and soil microorganisms, unstable in air and water, oxide SeO_2.
Organic		Selenodiglutathion	GSSeSG	Form of cellular transport in mammals.
		Trimethylselenium ($TMSe^+$)	$(CH_3)_3Se^+$	Form of disposal by organism via urine.
		Dimethylseleniure (DMSe)	$(CH_3)_2Se$	Volatile gas produced by soil microorganisms or plants.
		Dimethyldiseleniure (DMDSe)	$(CH_3)_2Se_2$	
		Seleno-cysteine (SeCys)	$HSeCH_2CHNH_2COOH$	Molecule considered the-21st amino acid, well present in mammalian tissues to constitute specific selenoproteins.
		Seleno-methionine (SeMet)	$CH_3Se(CH_2)_2CHNH_2COOH$	Amino acid very present in plants and yeast, reaction intermediate or storage form.
		Seleno-proteins	various formulas	multiple functions

***Table 1 :** The most common forms of selenium in the environment*[46].

2- BIO-AVAILABILITY OF SELENIUM

The bio-availability of Selenium depends primarily on its chemical state. The organic forms are generally more accessible than inorganic (Selenate and Selenite). Although many authors conclude, that selenate is take more effectively than the selenite[31-36].

Banuelos31suggests that soil with high Redox value, in arid region, has probably selenate as main compound in solution form, while acidic or neutral soils are not likely to havemany selenate. Selenium accumulation was increased in crop plant in clayey soil and hydrated oxide content better than other soils[37]. According to its ingestion, Thiry and al.[38]have noted four (04) types of Selenium : (i) the Selenium called « non bio-available » is not absorbed through the intestine, (ii) the Selenium called « bio-accessible » is soluble in the intestines, and has the ability to be absorbed across the intestinal mucosa (iii) the Selenium called « bio-available » which is absorbed and transported via the blood stream to the tissues and organs.

3- SELENIUM AND HEALTH

Selenium is a mineral that is needed by the body in small quantities. The body uses Selenium to produce enzymes and hormones to detoxify harmful substances and strengthen the immune system. People living with HIV / AIDS seem to have an increase need in Selenium compared to people without the HIV/AIDS disease[39]. We note an increasing interest for the Selenium due to its properties as antioxidant. The Recommended Nutrient Intakes (RNIs) by the World Health Organization (WHO) for this micronutrient (Se) have values smaller than the recommended by the U.S. / Canada[40]. At least 15 seleno-proteins have been specified, and 10 others exist, one of which is a component of the mitochondrial sperm cell capsules. A shortage in Selenium could cause damages to the seleno-proteins responsible for the development of the sperm[41].

Keshan disease : acute Selenium deficiency caused diseases for people; typical events are fatigue after even a slight exercise, cardiac arrhythmia and palpitations, loss of appetite, heart failure, cardiomegaly and congestive heart failure. The possibility that increased Selenium intake may protect against the development of cancer in humans has aroused great interest[42,43].

Selenium compounds are generally very efficiently absorbed by human, and the absorption of Selenium does not appear to be under the homeostatic control[44].

For example, the absorption of Selenium as selenite is greater than 80 percent while the form of selenate or as seleno-methionine may be greater than 90%[45;46,37].

Selenium has a role in the metabolism and in the thyroid regeneration of vitamin C. This element is also a component of myosin (muscle protein) and at low dose stimulates the immune and pancreatic system. It is essential in male fertility by participating in the synthesis of the progesterone and spermatogenese[46,47].

3.1. Biological effects and clinical symptoms in the case of deficiency in Se

Moderate Selenium deficiency is often observed in patient is having[28,48,49] :

- A decrease in immune-competence ;
- Developed a cancer : Selenium deficiency is a cause or a consequence of the development of tumor cells ;
- Developed cardiovascular diseases, including myocardial heart attack ;
- Disturbances of reproduction miscarriages pregnancy and reduced male fertility ;
- Thyroid disorders such as the development of goiter and hypo-echogenicity of the gland.

And in general, in humans, an important Selenium deficiency leads to muscular dystrophy, bone or embryonic deformities. Despite the decrease in Selenium intake, no overt signs of deficiency have yet been observed in Europe. Contributions in suboptimal Selenium may reduce the production of seleno-proteins, which in turn can affect DNA repair, alter immune responses and anti-inflammatory and weaken the protective mechanisms against diseases like cancer and cardiovascular diseases.

3.2. Biological effects and clinical symptoms in the case of excess in Se

Selenium excess (Selenosis) is less common than those related to a Selenium deficiency. The precise value of the harmful Selenium dose for humans is still uncertain but never the less, the World Health Organization (WHO) recommends a maximum intake of 400 µg/d adulte[50]. According to the WHO, inorganic forms are more toxic than organic forms. Also, in inorganic forms selenite would be more harmful than selenite[51]. Poisoning causes bronchial and dermal irritation, blurred intestinal (vomiting, diarrhea, pain), heart problems, specific odor of skin and breath (odor of garlic), abnormal hair and fingernails, as well as peripheral neuropathies irritability and fatigue exacerbated.

3.3. Selenium and cancer

The role of Selenium in cancer development has been extensively studied in recent years[52-55]. Although there are plausible mechanisms by which seleno-proteins could reduce the risk of cancer (eg by addressing the free radicals that cause damage to DNA), the researchers concluded that the evidence that foods containing Selenium confer protection against the risk of cancer are limited, however, exception made of the prostate cancer. Seleno-proteins can reduce the risk of prostate cancer because they are involved in the production of testosterone, which is an important regulator of normal and abnormal prostate growth.

3.4. Selenium and HIV/AIDS

The human body has the ability to produce antioxidant enzymes. To do this, it uses the B-complex vitamins and several minerals including copper, manganese, zinc and Selenium. Given the important role, that Selenium plays in the manufacture of antioxidant enzymes, and wherein the body of HIV/AIDS does not produce enough of antioxidant enzymes, several HIV/AIDS take supplements of this mineral. Selenium supplements appear to stimulate the function of immune cells, at least under laboratory experiments. Researchers following PLHIV/AIDS found that patients with a blood Selenium levels lower than normal were at increased risk of death compared to Living with HIV/AIDS with normal levels of Selenium. Thus, it is possible that Selenium supplementation can prolong survival when combined with an HAART HIV[56].

4- SELENIUM IN PLANTS

Plants were classified according to the Selenium behavior in human body by the

North American organism Flora[57] :

- Non-accumulating plants have a Selenium content of less than 25 µg/g of dry matter.
- Accumulating plants may contain from 25 to 1000 µg of Selenium per gram of dry matter.
- Hyper-accumulating plants accumulate > 1000 µg of Selenium per gram of dry matter.

Plants are a vital link in the transport Soil-human. They are a vital source both in food and feed. Cereals are a prime example : their Selenium content is higher than in other food plants (legumes, for example) and they are the basis of food and feed in many countries[46].

4.1. Wheat position in nutrition

Rice and wheat are basic food for many populations in the world. The increase of the Selenium content in wheat may represent a good approach to the strategy of increasing the daily intake of Selenium for population, which in return be translate into improved health Public and significant cost savings in the health care[58,59]. Cereals are very important foods for human nutrition, due to the high content of carbohydrates, proteins, dietary fibers and minerals such as Selenium, calcium, zinc and iron[36,13]. The wheat, and therefore breads and cereals, are supposed to be a good source of Selenium.

In Algeria, different studies have confirmed that the population consumes cereals and cereals products especially semolina at high amount, about 70% of the total consumption, and estimated that most people obtain around half their Selenium from wheat[13,60].Selenium status of populations is dependent on the Se content of soils and food crops produced thereon[5]. Beladel et al[13] showed that the concentration of Se in wheat was a reflection of Se levels in regional soils.

	States	Mean selenium content in wheat (µg/Kg)	Coefficient of variation	Mean selenium content in soil (µg/Kg)	Se (soil)/Se (wheat)
Western	Tiaret	21 ± 8	0,38	2210 ± 57	105 ± 7
	Khemis miliana	60 ± 8	0,13	3882 ± 71	64 ± 9
	Saida	28 ± 9	0,32	2525 ± 63	90 ± 7
Eastern	Guelma	28 ± 7	0,25	2691 ± 55	96 ± 8
	Constantine	32 ± 11	0,34	3354 ± 67	104 ± 6
	Khroub	153 ± 49	0,32	6230 ± 101	40 ± 2
	Setif	34 ± 8	0,24	3169 ± 61	93 ± 8
	Oum el-bouaghi	55 ± 5	0,09	3117 ± 58	56 ± 11
	Souk ahras*	63,3 ± 15	–	–	–

*A. N. Merzoug., H. Merazig & L. Houam. (2013).[60]

Table 2 : Selenium content of wheat and soil in Algeria.

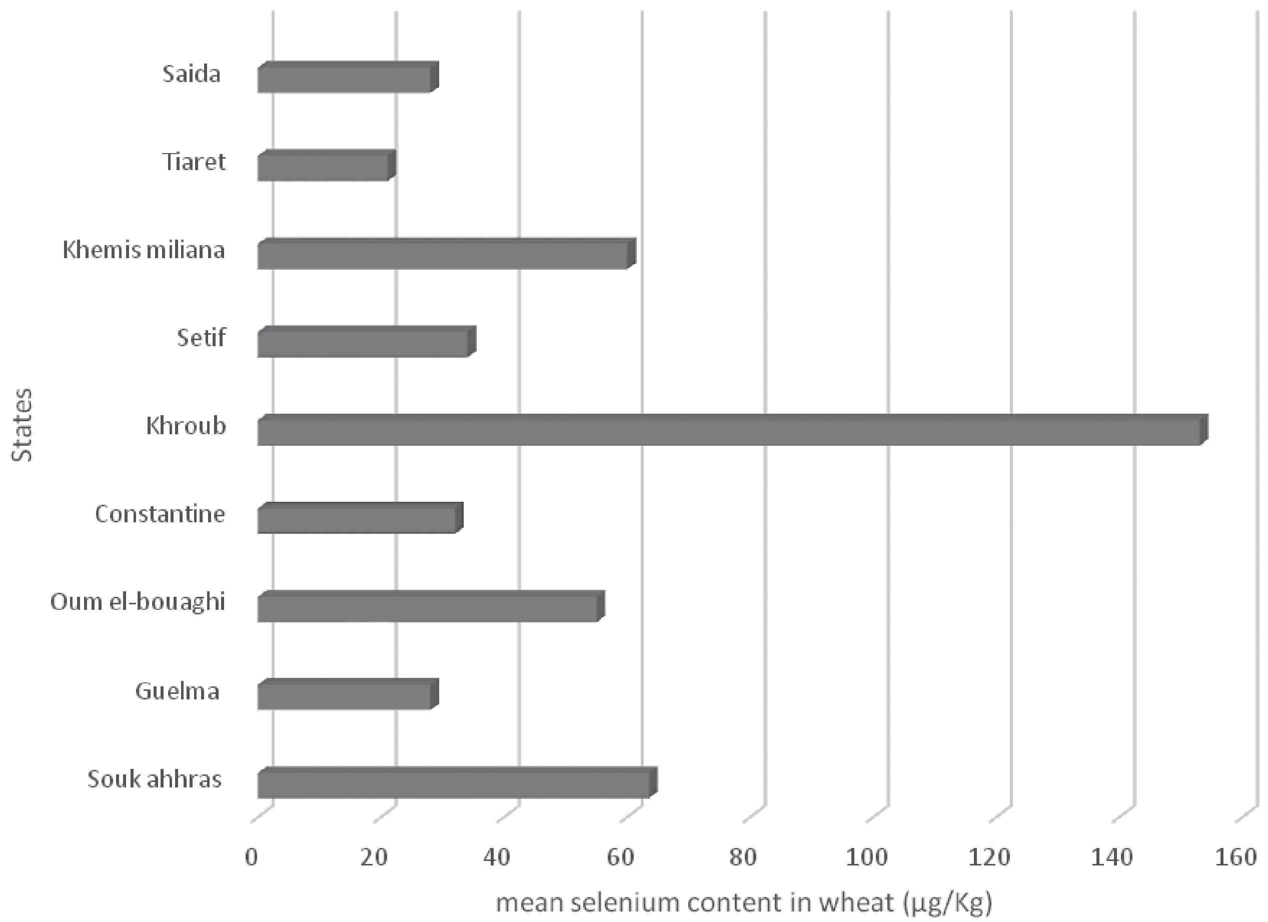

Figure 1: Selenium content of wheat in Algerian regions (distribution from western to eastern states) 13

5- SELENIUM IN SOIL

The main source of Selenium is the diet and thus, levels of Selenium in soils generally reflect the status of Selenium in human populations[61-63].

We can distinguish two types of soil : Soils poor in Selenium content, known seleniprive soils, they have less than 0.2 µg/g of Selenium[64,65] ; in some regions of China and the USA, Selenium concentration does not exceed 0.02 µg /g. In counterpart selenifer soils have greater than 1.5 µg/g[66,67] of Selenium content. In Ireland, the Selenium content of the soil can vary from 1 to 1200 µg/g, and similarly, the soil in some parts of USA, India and China exceed a concentration of 10 µg/g[66-67,46]. Selenium is toxic at high concentrations, standards have been established : in Europe (European Standard - Directive 98/83/EC and Decree No. 2001-1220 of 20/12/2001), Australia, Canada and Japan, the Selenium drinkable threshold in water is 10 µg/L. However the US standard set this value to a 5 times higher or 50 µg/L. Note that there is no standard for irrigation water : however, the maximum concentration in irrigation water recommended by FAO is 20 µg/L[46]. The Selenium distribution between aqueous and solid phases depends on the content in organic matter and hydroxides material on clays.

Selenate is predominantly present in aerated soils, dry alkaline. This form is more soluble and has a low capacity to be adsorbed to soil particles. It is considered the most bioavailable to plants. Selenium supplements are available in two forms :

- Biological form : seleno-cysteine, Selenium citrate, yeast and Selenium-rich kelp ;
- Abiotic form : sodium selenite, sodium selenate.

6- STRATEGIES DEVELOPED TO INCREASE SELENIUM CONTENT IN WHEAT CROP

Micronutrient deficiencies, particularly selenium, represent a public health problem with significant physiological and economic consequences[68].The assessment of the importance of these deficiencies, their distribution and the risk factors makes it possible to select the target groups and the interventions to be implemented[69].

There is growing support for the notion that agricultural interventions have an important role to play in efforts aimed at improving the nutritional status of populations. Therefore, strategies to improve the nutritional status of populations should include efforts to increase dietary diversity[69]. Transgenic and biofortification are two strategies applied throughout the world in order to improve the nutritional status[70].The potential interest of GMOs in nutrition can be considered from several angles[71,72]. The first is general, linked to the increase in the availability of food resources and therefore to the fight against under nutrition. The second is specific and relates either to the correction of imbalances of nutritional composition of the plant in order to optimize its intrinsic qualities or to the enrichment of the plant in specific nutrients in order to combat deficiencies, According to the Codex Alimentarius[73], the definition of a hazard applied to the food is as follows : « Danger is a biological, chemical or physical agent present in a food or a condition that may have an adverse health effect ». This definition may apply to genetically modified organisms in a public health or environmental context. In human and animal health, when new proteins are produced, the emerging risks are of four types : toxicological, allergic, functional and nutritional which made these strategies less adapted.

On the other hand, agronomic bio-fortification is to adapt agricultural practices to increase the concentration of Selenium in the edible parts of the plant[74]. The Agronomic bio-fortification strategies are based on the application of fertilizer and or solubility and mobility of mineral elements in the soil (change of pH, redox potential, for example)[75,76].

In many In this case, this strategy can lead to a rapid improvement in Micronutrients in a population, at a very reasonable cost, different studies on micronutrient biofortification have shown its beneficial impact on public health, prevention and remediation[77,79]. In the General Principles for the Addition of Nutrients to Foods[80,81], the Codex Alimentarius Commission stipulates that any enrichment program must be justified. The strategy of biofortification in selenium has been adopted in different parts of the world since 1980s ; in regions of China where selenium deficiency is endemic, salt was enriched with sodium selenite (15 mg/kg). This measure made it possible to increase the average daily intake of selenium from 11 µg to 80 µg and effectively lowered the prevalence of Keshan syndrome. Sodium selenate is currently used to enrich various types of food. In Finland, for example, sodium selenate is added to the fertilizers used in areas where the soil is poor in selenium ; Measurable increases in selenium content in milk, meat and cereals obtained from these soils were observed after six months[73,80,82] (see Table 03). In the United States of America, sodium selenate is included in the composition of certain beverages for athletes (about 10 µg per liter) and for the enrichment of baby foods[80]. Until 1985, bread provided about half of the selenium intake in the United Kingdom, but after 1985, when European wheat was replaced by Canadian wheat, this proportion fell to about 20%[80]. While biofortified crops are developed to provide nutrition benefits for the population, they may also offer agronomic benefits, since minerals help plants resist diseases and other stress factors[83].

Region or country	Selenium intake (Mean ± Standard Deviation)
China, disease-free	13 ± 3
China, selenifer area	1338
Southern Sweden	40 ± 4
Finland, before adding Selenium to fertilizers	26
Finland, after adding Selenium to fertilizers	56
UK, 1974	60
UK, 1995	33
Italy	41
France	47
USA	80 ± 37
Canada	98 – 224
Venezuela	80 – 500

Table 3 : Geographic differences in selenium intake (µg/day)[40].

7- STATUS OF SELENIUM IN THE WORLD

Selenium status of a given population depends on several factors, namely :

- Nutritional habits of the population.
- Selenium concentration in soil where plants and vegetation were cultivated[7,66].
- Seasonal variability and geochemical and climatological conditions may also affect the Selenium concentration of wheat[72,84,85].

In overall, there is no consensus on the optimal intake of Selenium. Moreover, the bioavailability of Selenium can range from a food source to another one ; this can be influenced by many factors such as the chemical form of the element or of the interactions with the food components[86].

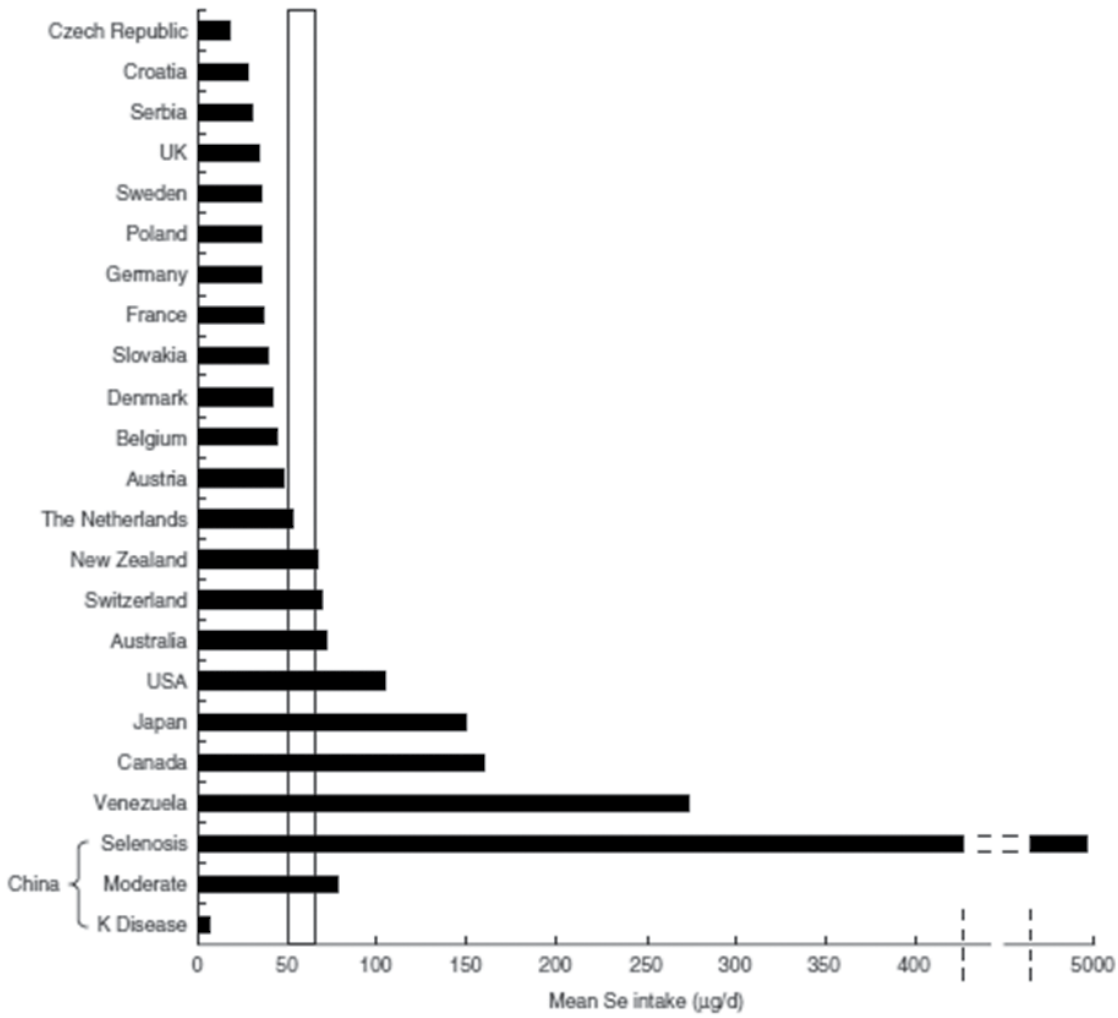

Figure 2 : Selenium intake (µg/day/person) based on different countries (Boxed area : recommended daily intake for adults) (Rayman 2005)[46].

CONCLUSION

Food diversification is important when it comes to improving the intake of essential nutrients. Selenium plays a major role in public health and serves as a marker of overall intake micronutriments[87]. Differences in Selenium concentration within countries are noted, see Table 3, and should be taken into account when the question of the use of supplements at international level arises. The values range from 0.001 mg/kg in the South-West of Australie[88,89,40] to 30 mg/kg in highly selenifer of the Southern area of the Dakota. The United States and Canada have concentrations relatively much higher from 0.2 to 0.6 mg/kg[85], Canada's result is a good exemple of biofortification as it moved from a low concentration[80] to a greater concentration in two decades[85]. Eastern Europe and New Zealand have generally lower levels with an average of 0.028 mg/kg. In general, the European wheat contains lower Selenium content than the North American wheat Selenium content. Fluctuations in the Selenium concentration in many communities of Northern Europe reflect the intrinsic low Selenium content due to glacial soils and explains the extent to which Selenium supplementation in fertilizers has managed to increase the Selenium content of cereal grains, milk and other animal products[89].To reduce the risk of selenosis, it is advisable to import cereal seeds poor in Selenium. Grains with low Selenium are selected in China, India and Venezuela[89]. In Algeria, the main source of selenium comes from the high consumption of wheat and its derivatives[13,14,90]. According to the recommendations of the CODEX Alimentarius program, the biofortification stays an interesting way to improve the level of selenium intake in foods ration. The biofortification appears as a solid option to improve wheat selenium content and availability. Still another answer to malnutrition is to creating new versions of staple food crops that come out of the ground with higher selenium content.

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CAPTIONS

Table 1 : The most common forms of selenium in the environment[46].
Table 2 : Selenium content of wheat and soil in Algeria[13].
Table 3 : Geographic differences in the Selenium intakes (µg/day) for adults[40].
Figure 1 : Selenium content of wheat in Algerian regions (distribution from western to eastern states)[13].
Figure 2 : Actual selenium intake (µg/day/person) based on different countries.
(**Boxed area :** recommended daily intake for adults) (Rayman 2005)[46].