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Selenium in Australia: Selenium status and biofortification of wheat for better health

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Abstract

Selenium (Se) is an essential micronutrient for humans and animals, but is deficient in at least a billion people worldwide. Wheat (*Triticum aestivum* L.) is a major dietary source of Se. The largest survey to date of Se status of Australians found a mean plasma Se concentration of 103 μg/l in 288 Adelaide residents, just above the nutritional adequacy level. In the total sample analysed (six surveys from 1977 to 2002; $n = 834$), plasma Se was higher in males and increased with age. This study showed that many South Australians consume inadequate Se to maximise selenoenzyme expression and cancer protection, and indicated that levels had declined around 20% from the 1970s. No significant genotypic variability for grain Se concentration was observed in modern wheat cultivars, but the diploid wheat *Aegilops tauschii* L. and rye (*Secale cereale* L.) were higher. Grain Se concentrations ranged 5–720 μg/kg and it was apparent that this variation was determined mostly by available soil Se level. Field trials, along with glasshouse and growth chamber studies, were used to investigate agronomic biofortification of wheat. Se applied as sodium selenate at rates of 4–120 g Se/ha increased grain Se concentration progressively up to 133-fold when sprayed on soil at seeding and up to 20-fold when applied as a foliar spray after flowering. A threshold of toxicity of around 325 mg Se/kg in leaves of young wheat plants was observed, a level that would not normally be reached with Se fertilisation. On the other hand sulphur (S) applied at the low rate of 30 kg/ha at seeding reduced grain Se concentration by 16%. Agronomic biofortification could be used by food companies as a cost-effective method to produce high-Se wheat products that contain most Se in the desirable selenomethionine form. Further studies are needed to assess the functionality of high-Se wheat, for example short-term clinical trials that measure changes in genome stability, lipid peroxidation and immunocompetence. Increasing the Se content of wheat is a food systems strategy that could increase the Se intake of whole populations.

Keywords: Selenium status; Wheat; Rye; Genotypic variation; Biofortification

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Introduction: selenium essential for human health

Although not proven to be essential for higher plants, selenium (Se) is an essential micronutrient for human and animal health, with antioxidant, anti-viral and anti-cancer effects [1,2]. Cancer prevention appears to require a supra-nutritional Se intake, but in some regions Se is declining in the food chain [3,4], and new strategies are needed to increase its intake. It is estimated that at least a billion people are Se deficient [3], and its deficiency in much of Sub-Saharan Africa has been postulated as a determinant of the rapid spread of HIV/AIDS in this region [5].

Clarifying the Se status of South Australians

Few surveys of Se levels in Australians have been conducted and most have been small. Given the geographical variability in Se intake and blood levels and their sensitivity to changes in the food supply, it is necessary to use local data to accurately monitor Se status. In order to determine the Se status of healthy South Australian residents, a survey of nearly 300 Adelaide blood donors was conducted. The study yielded a mean plasma Se concentration of 103 μg/l [6], which is above that of most countries, and just above the estimate of 100 μg/l required for maximising the activity of the important antioxidant selenoenzyme, glutathione peroxidase [1]. However, only 8% of men surveyed reached 120 μg/l Se, a plausible target for maximum protection against prostate cancer [7–9], which is the most commonly diagnosed solid tumour and the second leading cause of cancer mortality in Australian men [10]. These findings indicate that many Australian men (given that most previous Australian post-1990 studies found lower Se levels than this study) would be in the responsive range for lower risk of prostate cancer by increasing their Se intake. We conclude that men living in Australia with a plasma Se concentration below 100 μg/l would be likely to benefit from Se supplementation.

The inclusion of data from earlier South Australian surveys conducted by the South Australia Research and Development Institute (to give a total sample size of 834 individuals) resulted in the largest human Se survey yet conducted in Australia, and it showed a 20% decline in the Se status of South Australians sampled from 1977 to 1988 [6] (see Fig. 1). This may be due to changes in dietary composition and/or a decline in the mean Se concentration of South Australian wheat (*Triticum aestivum* L.), given the importance of wheat as a source of dietary Se [11,12], and this apparent decline will be discussed below in the context of surveys of Se concentration in wheat grain.

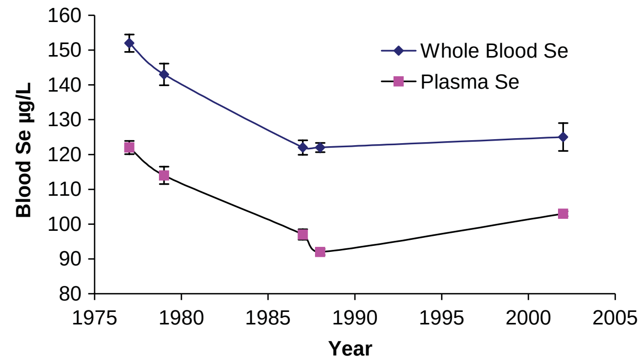

Fig. 1. Trend in whole blood and plasma selenium concentrations in South Australians, 1977–2002. Standard error bars included (from [6]).

Less-healthy sub-groups of the South Australian population than the groups surveyed in this study, such as heavy smokers [13,14], people with low socioeconomic status and the frail elderly [15], could be expected to have substantially lower levels of blood Se. Pregnant and lactating women [16,17] and infants [18] are also at risk of low Se status.

Strategies to increase selenium intake

Background

Given that the Australian population (and *a fortiori* the populations of the many countries with a lower Se intake) would be likely to benefit from an increased Se intake, how could this be best achieved? Options include increased consumption of higher-Se foods (such as Brazil nuts, cereals, meat and fish) through education; addition of Se to water supplies (as is done with fluoride in Australia); individual supplementation; food (process) fortification; and biofortification, including supplementation of livestock, use of selenium fertilisers, and plant breeding for enhanced selenium accumulation. Each option shall be discussed briefly in the following two sub-sections.

Dietary composition, drinking water, supplementation, food fortification

Globally, wheat is one of the most important dietary sources of Se. The sensitivity of a population's Se status to changes in its source of wheat is illustrated by the United Kingdom, where blood Se levels have declined by around 50% since changing from high-Se Canadian and USA-grown wheat to low-Se European wheat in the mid-1980s [1]. In Australia, it is estimated that nearly half of our Se intake is provided by wheat [11]. Brazil nuts provide the most concentrated natural food source