Selenium in Biology and Medicine

Part A

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These studies may not conform to peer review standards. Therefore, the results are not conclusive.

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45

Relative Bioavailability of Inorganic and Natural Selenium

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INTRODUCTION

Research efforts have identified groups of people with low selenium intakes and presumed selenium deficiency based on low blood selenium levels. Inhabitants of New Zealand (*1*), Finland (*2*), and China (*3*) often have low blood selenium. Individuals with therapeutic diets low in selenium (*4*), people undergoing parenteral administration (*5*), and alcoholics with cirrhosis (*6*) can also be selenium deficient. Epidemiological studies have shown that low blood selenium levels have been linked to increased incidence of cancer (*7,8*) and heart disease (*9*).

Thus, it may be necessary to supplement the human diet with selenium in ideally the most bioavailable form of selenium. Approaches to the determination of bioavailability of physiologically important levels of selenium have been diverse and have yielded data of uncertain significance. One factor that contributes to this variation is the fact that selenium occurs in so many different chemical forms: Se^0 in elemental selenium, Se^{4+} in SeO_3^{2-} (selenites), Se^{6+} in SeO_4^{2-} (selenates), and Se^{2-} in selenomethionine or incorporated in protein by replacing sulfur in sulfur-containing amino acids.

Studies using species-specific criteria such as exudative diathesis or pancreatic fibrosis (*10,11*) in chicks have also yielded diverse and highly variable data. For instance, both criteria indicate a superior availability of plant over animal selenium sources, but a very low availability of selenomethionine was found for protection against exudative diathesis and a very high availability for protection against

pancreatic fibrosis. Variation was wide in determining effectiveness of a given selenium source fed at different levels (nonlinear response) and fed at the same levels in different experiments. However, in all cases, selenite was the most available form of selenium. A good slope ratio assay has been developed relating plasma glutathione peroxidase activity to selenium intake in selenium-depleted chicks. Selenite was the most available followed by selenomethionine, fish meal, corn meal, and soybean meal (*12*).

Very little data occur in the literature concerning the human bioavailability of different forms of selenium. A New Zealand study showed that selenomethionine showed more complete absorption, greater retention, and smaller endogenous urinary and fecal losses than selenium from selenite or mackerel (*13*). A human dietary study (*14*) which monitored urinary selenium concluded that the selenium in diary products and eggs is more readily absorbed than other food groups. A recent study (*15*) showed that a selenium-rich yeast and selenium-rich wheat were much more available to Finnish men of low selenium status as measured by plasma selenium and glutathione peroxidase.

The present study was undertaken to investigate which form of selenium, of those available for human supplementation, was most bioavailable.

EXPERIMENTAL

There were three forms of selenium used for this study. Sodium selenite (inorganic) was Fisher reagent grade. Amino acid chelated selenium (chelate) was obtained from Essential Organics as containing 50 μg of selenium. Grow Company provided the selenium yeast (yeast) as a light brown powder, 200 μg/g.

The animals used in this study were male Sprague-Dawley rats weighing 50 g. They were divided into 9 groups of 5 animals each so that the average weight of each group was the same. The rats were then put on a powdered selenium-deficient diet (Nutritional Biochemicals) and distilled water for a period of 2 weeks to deplete selenium stores. Then each group was given the same diet to which selenium had been supplemented at concentrations of 50, 100, and 200 ppb in one of the three forms: inorganic, chelate, and yeast. At the end of 33 days, the rats were fasted overnight. The blood was collected by cardiac puncture into a culture tube with EDTA and the rats were then sacrificed by anesthesia. The liver was collected and frozen until analyzed.

TABLE 1. Dose–Response Assay for Different Forms of Selenium in the Blood of Rats Supplemented with Selenium

Form of selenium	Selenium in food (ppb)	Average blood selenium (ppb)
Inorganic	50	463 ± 174
Inorganic	100	790 ± 245
Inorganic	200	1249 ± 356
Chelate	50	332 ± 219
Chelate	100	560 ± 308
Chelate	200	811 ± 483
Yeast	50	598 ± 69.0
Yeast	100	799 ± 163
Yeast	200	1633 ± 226

One gram of liver or 1 ml of blood was mixed in a crucible with 10 ml of ashing aid prepared from 80 g Mg $(NO_3)_2$ and 10 g of MgO in 200 ml of distilled water (*16*). The sample was placed in a 110°C oven overnight to remove the water. Then it was ashed in a muffle furnace overnight at 500°C. The selenium was determined fluorometrically by a standard procedure using dimethylaminonaphthalene (*17*).

RESULTS AND DISCUSSION

The blood results are presented in Table 1. The results indicate that for all levels of supplementation the order of blood selenium concentration is yeast > inorganic > chelate. There seems to be a great deal of variation within groups as seen by the magnitude of the standard deviation. This effect has also been seen in previous selenium supplementation studies. Of the three forms of selenium, the yeast group had the smallest absolute and relative deviation.

TABLE 2. Dose–Response Assay for Different Forms of Selenium in the Liver of Rats Supplemented with Selenium

Form of selenium	Selenium in liver (ppb)	Average liver selenium (ppb)
Inorganic	50	490 ± 64
Inorganic	100	727 ± 43
Inorganic	200	1306 ± 369
Chelate	50	555 ± 210
Chelate	100	750 ± 129
Chelate	200	1129 ± 76
Yeast	50	651 ± 287
Yeast	100	908 ± 162
Yeast	200	1597 ± 160

TABLE 3. Relative Bioavailability of Different Forms of Selenium

Form of selenium	Slope of plot	Correlation coefficient	Relative bioavailability (%)
	Blood		
Inorganic	5.15	0.9956	100
Chelate	3.10	0.9868	60.2
Yeast	7.11	0.9889	138
	Liver		
Inorganic	4.34	0.9817	100
Chelate	3.82	0.9999	88.0
Yeast	6.39	0.9977	147

The liver results are presented in Table 2. For the high and low levels of supplementation, the order of liver selenium concentration is yeast > inorganic > chelate. This is the same order as obtained from the blood results.

The relative bioavailability was calculated by comparing the slopes from the dose–response assays for blood and liver. The slopes were calculated from a linear regression analysis. The slope of the inorganic plot was divided into those of the other groups, and the result was multiplied by 100 to get the bioavailability relative to the inorganic as a standard. The results are shown in Table 3.

The relative bioavailability in both blood and liver was yeast > inorganic > chelate. It is surprising that the chelate selenium which was supposed to be an amino acid chelate fared so poorly in the bioavailability study. If the selenium is in a chelate form, then it must be very stable and is in competition with chelating cellular acceptor sites on the mucosa or other tissues (*18*). Or it may be in the +4 oxidation state as selenium dioxide, which is the commonly used and least expensive form of selenium. The yeast in which the selenium is probably covalently bound to amino acids in the −2 state was the most bioavailable. The yeast is grown in a nutrient medium containing selenium dioxide, harvested, hydrolyzed, and spray dried. Previous studies have also shown that organic selenium such as selenomethionine (*14*), selenium-rich wheat (*15*), and selenium yeast (*15*) is more bioavailable than selenite.

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