Production of Functional Korean Ginseng by Selenium Supplement in Hydroponic System

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Abstract

Korean ginseng (*Panax ginseng* C.A. Meyer) was tested to demonstrate that production of this plant with a nutritionally important selenium (Se) is possible, making it a functional ginseng with concentrated Se supplement and the Se incorporated into the enriched Korean ginseng occurs in a soluble, metabolically available form. Sequential extraction was used to assess the degree of solubility of Se. Se content of Korean ginseng represented linear accumulation tendencies in proportion to the increase of Na_2SeO_4 concentration and duration in the nutrient solution. Results from this solubility experiment indicate that the accumulated Se achieves very soluble form, consequently this Se-enriched plant can economically supply 100 % of Se content in it to human. Two-year-old Korean ginseng containing an anticarcinogenic Se compound can be recommended for growth in a hydroponic system.

INTRODUCTION

The trace mineral selenium (Se) is an essential nutrient of fundamental importance to human biology. Selenium is a key component of a number of functional selenoproteins required for human health. There is evidence that Se has an antioxidant role through the selenoenzyme glutathione peroxidase, but also through other more recently discovered selenoenzymes (Murphy and Cashman, 2001). A number of Se-fortified food products are available in certain countries, although an excess Se can be problematic. But, these products aren't popular in Korea. Nevertheless, Lee and Park (1998) evaluated the accumulated contents of Se in leafy vegetables in hydroponics and the effect of Se on the growth and internal quality of endive. Lee et al. (2001b) showed that Se supplement increased functional quality of Korean mint, native to east Asia through increasing essential oil content. Ginseng is one of the most important medicinal plants throughout the world. Therefore if we can develop a Se-fortified Korean ginseng which meets the need and expectation of consumers, it may enable the promotion of health and could be an important new agricultural product. Therefore, this study evaluated the optimal concentration of anticarcinogenic Se compound, in consideration of bioavailability, to promote Korean ginseng quality.

MATERIALS AND METHODS

Plant Materials

This experiment was carried out in the greenhouse of Korea University. The tested plant was 1-year-old Korean ginseng (*Panax ginseng* C.A. Meyer) that was taken from Kyonggi province, Korea. Before transplanting, the seedlings were soaked in GA 50 ppm solution for 3 hours to break bud dormancy of 1-year-old root and then thoroughly rinsed with distilled water (Park et al., 1999).

The 14 ginseng seedlings were transplanted to the beds (50 × 31.5 × 22 cm) filled with water (25 L) for water culture with 45° in 3 cm depth on 31 March 2001 (Lee, 1996). They were harvested on 13 September 2001. The experiment design was a randomized complete block design with three replications.

The composition of a nutrient solution was as Table 1. The solution EC was maintained at 0.5 mS cm^{-1} in the leaf–expanding stage and then 1.0 mS cm^{-1} in the fully leaf-expanded stage (Park et al., 1999). Nutrient solutions were aerated 45 minutes per hour and exchanged every 15 days. The light intensity in the greenhouse was 300 ± 50 mol m^{-1} s^{-1}(70 percent shading) at 24 ± 2 ºC in spring season and 120 ± 30 mol m^{-1} s^{-1} (90 percent shading) at 32 ± 2 ºC in summer season and at that time the temperature of root zone was maintained at 16 ± 2 ºC and 26 ± 2 ºC, respectively.

For production of functional Korean ginseng, sodium selenate concentration of 0, 2, 4, 6, and 8 mg·L^{-1} was used to treat the plants 15 days and 30 days before harvest in water culture.

Analysis of Selenium Content

The ground samples of each plant (0.5 g) were digested in HNO_3 overnight (about 16h) and then a mixture of concentrated HNO_3/$HClO_4$). The digested samples were brought to a constant volume with deionized water, and the digests were analyzed for total Se by inductively coupled plasma spectroscopy (ICP).

Bioavailability Measurements

Determining potential bioavailability was conducted using a sequential extraction procedure that used duplicate 1.0 g samples in a 10:1 solution:solid ratio in the following sequence (Ramos et al., 1994): 1 M $MgCl_2$ for 2 h (water soluble), 0.04 M hydroxylamine hydrochloride in 25 %(v/v) glacial acetic acid for 2 h (reducible), 0.1 M HNO_3 + 30 % hydrogen peroxide at 70 ºC for 16 h (originally complexed), and concentrated HNO_3 and 30 % hydrogen peroxide for 2 h (residual). All samples were centrifuged at 4,300 rpm for 10 min, filtered, and solubilized extracts were analyzed by ICP (Fig. 1).

RESULTS AND DISCUSSION

An anticarcinogenic Se compound essential to human nutrition can be accumulated in Korean ginseng and be manipulated by control of the cultivation conditions: achieving a constant desired Se concentration in the plant tissue is dependant on the Se concentration in the nutrient solution and treatment term.

The Se concentration of ginseng root was from 19.5 to 40.9 µg·g^{-1}DW on the 15th day and from 34.9 to 59.4 µg·g^{-1}DW on the 30th day after treatment when sodium selenate from 2.0 to 8.0 mg·L^{-1} was added to the solution, thus demonstrating the ability to produce bulk quantities of plant material enriched with a Se compound (Fig. 2). Lee and Park (1998) reported that Se concentrations in leaf tissues increased in response to increased sodium selenate concentrations, as well as increased treatment time. When sodium selenate or sodium selenite was treated to 2.0 mg·L^{-1}, those corresponding Se accumulations were suitable levels for human consumption. Lee et al. (2001a) also showed Se content in Korean mint increased linearly when concentration of sodium selenate was increased, and the treatments of 1.0 and 2.0 mg·L^{-1} sodium selenate increased the functional quality of the plant. One ginseng root contained Se content enough to meet a recommended dietary intake (RDI) 200 µg, when sodium selenate 8.0 mg·L^{-1} in 15 days or 4 mg·L^{-1} in 30 days was supplemented. An anticarcinogenic Se function added to ginseng's medicinal effect may improve medicinal function of ginseng.

A series of extractions is used to assess bioavailability of Se in solid media. The procedure uses increasingly stringent extractants to characterize the solubility (water soluble, reducible, oxidizable, residual) of Se compound in a given matrix. These analyses assess the solubilization of the minerals from the plant tissue but not absorption as defined for "bioavailability"; however, minerals must be in a soluble form before uptake or metabolism by the body (Elless et al., 2000). For an element such as Se, that can be absorbed as the anion, absorption is high, generally exceeding 50 %, and sometimes approaching 100 %. But, the nutrient is absorbed in a form that is physiologically useful. In the case of Se, changes in plasma or serum concentrations are generally considered good indicators of bioavailability (Van Campen, 1999). Knowledge about the absorption of Se from foods or supplements does not predict its utilization, because bioavailability depends on the conversion of absorbed Se into a biologically active form and tissue retention (King. 2001).

Se accumulated in Korean ginseng was readily solubilized in the sequential extraction procedure (Table 2). More than 95 % of the total Se content in the enriched plant was solubilized in the water soluble and reducible fractions. Minerals extracted into solution earlier in the sequence are considered more bioavailable because the extractant strength progressively increases in the sequences (Elless et al., 2000). Therefore, Se in the plant was more readily soluble and potentially more available compared to commercially available mineral multivitamin. Inorganic forms of selenium have been shown to be absorbed rapidly but equally rapidly excreted in urine, in contrast to selenomethionine that was retained in the body (Thomson, 1998). Orser et al. (1999) also reported that the enriched *Brassica juncea* could be used as the source for a nutritional supplement that would provide the recommended daily intake for selenium in a more bioavailable form than commercially available yeast selenium supplements.

CONCLUSIONS

Se-supplemented ginseng can promote human health more because a Se-enriched ginseng in the optimal Se concentration was more readily soluble and potentially more available than commercially available mineral multivitamins. Therefore, our study presented a new way of producing ginseng as functional Korean ginseng in hydroponic system.

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Tables

Table 1. The composition of nutrient solution used in this study (Yamazaki, 1982).

Macro element	($me \cdot L^{-1}$)	Micro element	(ppm)
NO_3-N	6.0	Fe-EDTA	3.0
NH_4-N	0.5	Mn	0.5
PO_4-P	1.5	B	0.5
K	4.0	Cu	0.02
Ca	2.0	Mo	0.05
Mg	1.0	Zn	0.05

Table 2. Solubility of Se based on sequential extraction of Se supplemented Korean ginseng compound with multivitamin.

Treatment	Total Se Concentration (%)			
	Water soluble	Reducible	Oxidizable	Residual
Korean ginseng	66.4	30.7	2.2	0.7
Multivitamin [z]	0.0	100.0	0.0	0.0

[z] Values are referred from Elless et al. (2000).

Figures

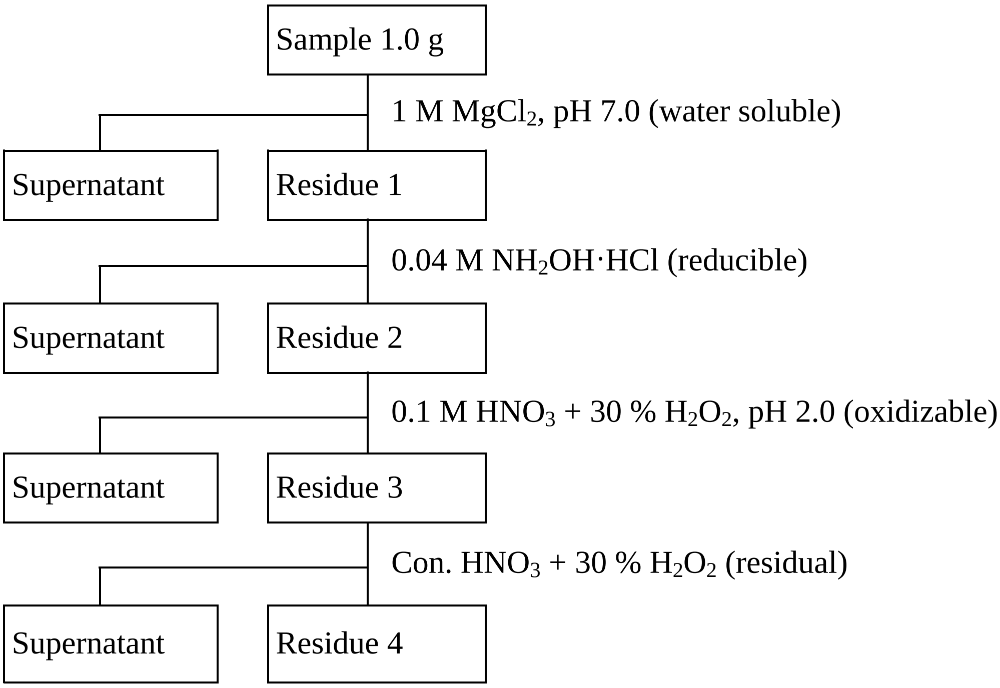

Fig. 1. Sequential fraction scheme of Ramos et al. (1994).

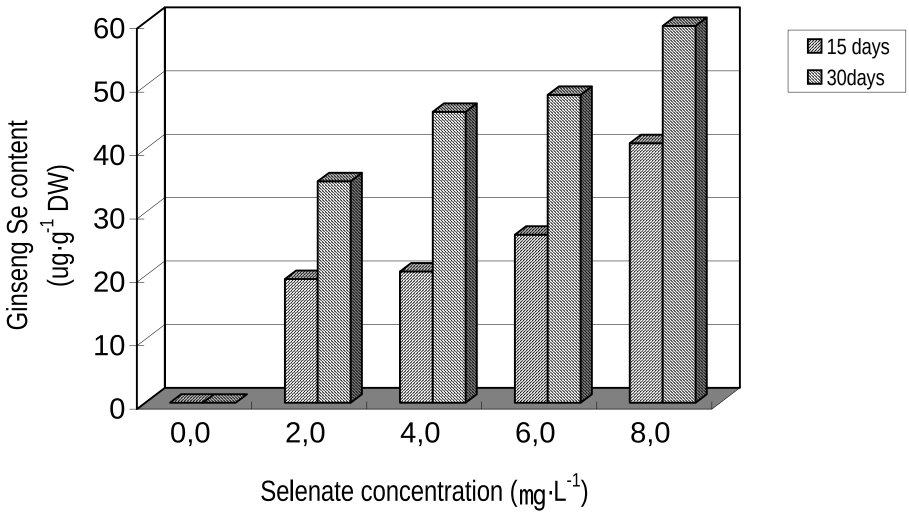

Fig. 2. Selenium concentration on the Se uptake of Korean ginseng on the 15th day and 30th day after Se treatment in water culture.