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*Research Article*

# The Feasibility of Using Tartary Buckwheat as a Se-Containing Food Material

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Tartary buckwheat (*Fagopyrum tataricum*) is a semiwild plant grown in the Himalaya region. Due to its high concentration of flavonoids and trace elements it is of interest for cultivation in other countries as well. The feasibility of increasing the concentration of Se in grain and in green parts of Tartary buckwheat has not yet been investigated. The aim of this investigation was thus to determine the concentration of Se in different edible parts of Tartary buckwheat treated with different concentrations of Na selenate using different techniques. In plants grown in soil fertilized once with 0.5 and 10 mg Se $L^{-1}$, Se was efficiently translocated from the roots to the leaves and seeds. Foliar spraying with 0.5 mg Se $L^{-1}$ increased Se content in leaves and seeds. Among the edible parts of Tartary buckwheat plants the highest content of Se in control and in treated groups was found in leaves, followed by seeds and stems. Regarding recommended Se concentration, edible parts of Tartary buckwheat were safe for human consumption. Soil fertilization with 0.5 and 10 mg Se $L^{-1}$ and foliar fertilization with 0.5 mg Se $L^{-1}$ are applicable for cultivation of Tartary buckwheat as a functional food enriched with Se.

## 1. Introduction

Tartary buckwheat (*Fagopyrum tataricum* Gaertn.) is a semiwild plant, characterized by high concentrations of the flavonoid rutin in leaves and grain. In northeastern Pakistan, Tibet, Yunnan, and Sichuan there exist in the same region both wild and cultivated types of Tartary buckwheat [1]. The grain of Tartary buckwheat is bitter in comparison to its more generally cultivated relative common buckwheat (*Fagopyrum esculentum* Moench). The bitter taste is due to a high concentration of flavonoids (rutin and its degradation product quercetin) in comparison to common buckwheat [2, 3].

Tartary buckwheat is a nutritious plant with many beneficial effects on human health [4]. It is a good source of vitamins B1, B2, and B6 and of proteins with high biological value [5]. It also has a relatively high crude fiber content. In China, leaves and young stems are used as well as the grain for human consumption, as are Tartary buckwheat sprouts in Korea.

Because of its nutritional quality there is interest in growing Tartary buckwheat outside its territory of origin, for example, in Luxembourg, Slovenia, Italy, and Sweden; experimental cakes and bread based on Tartary buckwheat have been prepared and tested in Slovenia, Sweden, and Italy [6–9].

Tartary buckwheat is an important source of dietary trace elements [10], but the feasibility of increasing the concentration of Se in grain and in edible green parts of Tartary buckwheat has not yet been investigated.

Selenium (Se) is a naturally occurring trace element that is present in the Earth's crust, soils, and minerals. It is not considered an essential micronutrient for plants, but recent studies have proposed several beneficial effects of this element in plants. Due to chemical similarities between Se and S, the uptake, transport, and assimilation of selenate in plants follow the sulfate pathway [11].

Interest in the biological impact of Se on the environment and food chains is increasing because it is an essential trace

nutrient for humans and animals, since it is an important component of various enzymes such as glutathione peroxidases, thioredoxin reductases, and iodothyronine deiodinases [12]. Low dietary intake of Se can lead to health disorders such as heart disease, hypothyroidism, and a weakened immune system [13].

Se enters the food chain through plants. Se content in plants is directly related to Se levels in the soil in which they are grown. The world's soils intended for agricultural production vary considerably with respect to the content of Se available for plants. As a consequence, people in many countries do not consume adequate amounts of Se [14]. Slovenia is among the countries with a low content of Se in soil [15]. Se-enriched crops could be used to supplement the human diet. The techniques used for enrichment are Se addition to soil [16, 17], foliar application of Se solution [18], soaking seeds in Se solution before sowing [19], and hydroponic cultivation in a nutrient solution containing Se [20].

The aim of our study was to determine how different Se treatments, especially at low concentrations, influence the uptake and distribution of Se in Tartary buckwheat plants. We attempted to identify the most appropriate way for obtaining Se-enriched Tartary buckwheat materials intended for human consumption. We hypothesized that it is possible to use Tartary buckwheat, a food rich in flavonoids, as an important nutritional source of Se as well.

## 2. Material and Methods

*2.1. Plants and Growth Conditions.* A domestic population of Tartary buckwheat plants (*Fagopyrum tataricum* Gaertn.) from Islek, Luxemburg, was grown outdoors on an experimental field of the Biotechnical Faculty, Ljubljana. The experiment lasted from June to August. Plants were arranged in three main blocks, where each block contained five plots sized 80 × 25 cm. On each plot a group of 15 plants was grown. One group of plants in each block was fertilized with an aqueous solution containing Na selenate at a concentration of 0.002 mg $L^{-1}$ on alternate days (seventeen times total) (SF 0.002), beginning at June 15. Se concentrations in selected Slovenian streams flowing through rural regions are much less than 0.002 mg Se $L^{-1}$ [21]. With this treatment we wanted to investigate whether such concentrations of Se in water could influence Se content in buckwheat plants if we used that water for irrigation. The second and third groups of plants were fertilized with an aqueous solution containing Na selenate at a concentration of 0.5 mg $L^{-1}$ (SF 0.5) and 10 mg $L^{-1}$ (SF 10), respectively, once in the experimental period, at the beginning of flowering, on July 2. With concentration of 0.5 mg Se $L^{-1}$ we wanted to examine if this concentration is high enough for use in production of Se-enriched Tartary buckwheat, suitable for functional food. 10 mg Se $L^{-1}$ is, based on our experiences, an effective concentration for successful accumulation of Se in plants. The fourth group of plants was foliarly sprayed with an aqueous solution containing Na selenate at a concentration of 0.5 mg $L^{-1}$ (FF 0.5), at the beginning of flowering, on July 2. Plants from the fifth group were used as a control (C). We collected three samples, one from each group, for each treatment and for the control. Plants were weighed and separated into individual plant parts (roots, stems, leaves, and seeds) and weighed again. Then plants were air-dried and weighed again to calculate the dry mass of the plant parts.

*2.2. Determination of Se Content.* Plants from each group within one block were analyzed for Se content in roots, stems, leaves, seeds, and husks. Samples were collected at the mature stage, and roots were washed with water and cut into pieces. All samples were freeze-dried (ALPHA 1-4, Osterode am Herz, Germany), weighed, and milled (Fritsch, Pulverisette 7, Idar-Oberstein, Germany). The total Se content was determined using hydride generation atomic fluorescence spectrometry (HG-AFS) in all plant parts of Se-enriched and nonenriched buckwheat. 2 g of each sample was weighed out in a Teflon tube (PTFE) and 0.5 mL of $H_2SO_4$ (96%) and 1.5 mL of $HNO_3$ (65%) were added. Teflon tubes were closed and heated on an aluminium block for 4 h at 80°C. The temperature was then increased to 130°C for 1 hour. After cooling, 2 mL of $H_2O_2$ (30%) was added and the samples were reheated at 115°C for 10 min; then 0.1 mL of 40% HF was added to samples containing fibres (leaves, stems, and roots) and heated for 10 min at 115°C; then finally 2 mL of $H_2O_2$ was added and the sample was heated for 10 min at 115°C. 0.1 mL of $V_2O_5$ was added to cooled samples and the sample was heated for 20 min at 115°C. Afterwards the reduction of Se(VI) to Se(IV) was carried out by the addition of concentrated 30% HCl and heating at 90°C for 10 min. After digestion and reduction of samples, they were diluted with ultrapure water (Mill Q + with Rephi Quatro U Pack 1, Merck Milipore, Darmstadt, Germany) and Se was determined by HG-AFS (P S Analytical LTD, model 10.044, Orpington, Kent, BR5, 3HP, England). Each sample was analyzed in three replications. The method of digestion and optimal measurement conditions has been described in detail by Smrkolj and Stibilj [22]. The accuracy of the method was checked with the certified reference material Spinach Leaves (NIST 1570a). There was good agreement between our results (114 ± 7 ng Se $g^{-1}$) and the certified value (117 ± 9 ng Se $g^{-1}$).

*2.3. Statistical Analysis.* The normal distribution of the data was tested using the Shapiro-Wilk test. Differences between control and treated plants were evaluated by ANOVA, followed by Tukey's *post hoc* multiple comparison tests. Differences at $P < 0.05$ were considered statistically significant.

## 3. Results and Discussion

During plant growth no visible symptoms of Se toxicity such as leaf necrosis or plant death were noticed. Table 1 shows the total Se content in roots, stems, leaves, seeds, and husks from Tartary buckwheat, treated with different techniques and concentrations of Na selenate. Fertilization of Tartary buckwheat with 0.002 mg Se $L^{-1}$ (SF 0.002) on alternate days had no statistically significant impact on Se concentration

Table 1: Concentration of Se in plant parts of Tartary buckwheat, treated with different techniques and concentrations of Na selenate.

| Treatment | Se content in plant parts (ng Se $g^{-1}$ lyophilized sample) | | | | |
|---|---|---|---|---|---|
| | Roots | Stems | Leaves | Seeds | Husks |
| Control (C) | $252 \pm 30^{aC}$ | $15 \pm 3^{abA}$ | $46 \pm 4^{aB}$ | $17 \pm 1^{aA}$ | $8 \pm 3^{aA}$ |
| Soil fertilization 0.002 mg Se $L^{-1}$ (SF 0.002) | $246 \pm 6^{aC}$ | $7 \pm 6^{bA}$ | $57 \pm 12^{aB}$ | $12 \pm 2^{aA}$ | $10 \pm 6^{aA}$ |
| Soil fertilization 0.5 mg Se $L^{-1}$ (SF 0.5) | $327 \pm 7^{bD}$ | $24 \pm 5^{aA}$ | $160 \pm 10^{bC}$ | $72 \pm 4^{bB}$ | $19 \pm 7^{aA}$ |
| Soil fertilization 10 mg Se $L^{-1}$ (SF 10) | $969 \pm 31^{cD}$ | $44 \pm 15^{cA}$ | $253 \pm 66^{cC}$ | $185 \pm 38^{cB}$ | $50 \pm 19^{bA}$ |
| Foliar fertilization 0.5 mg Se $L^{-1}$ (FF 0.5) | $251 \pm 7^{aD}$ | $15 \pm 3^{abA}$ | $139 \pm 9^{bC}$ | $65 \pm 6^{bB}$ | $15 \pm 2^{aA}$ |

Values with a different letter are significantly different ($P < 0.05$); small letters indicate statistically significant differences within a single column, while uppercase letters indicate statistically significant differences within a single row.

in roots, stems, leaves, seeds, and husks (Table 1). This concentration of Se was too low for efficient absorption and transportation to upper plant parts. Single soil fertilization with 0.5 mg Se $L^{-1}$ (SF 0.5) increased Se content in roots, leaves, and seeds, but not in stems and husks compared to the control group (Table 1). Single fertilization with 10 mg Se $L^{-1}$ (SF 10) significantly increased Se content in all plant parts compared to the control group. Foliar spraying with Se solution at a concentration of 0.5 mg Se $L^{-1}$ (FF 0.5) increased Se content only in leaves and seeds compared to the control group. Buckwheat plants readily absorbed the Se in SF 0.5, FF 0.5, and SF 10 treatments and transported it to leaves and seeds. Our results are in agreement with Li et al. [23] who reported that, in contrast to selenite, selenate is not readily assimilated in organic forms in roots but is highly mobile in xylem transport.

Concentration of Se in seeds of plants from FF 0.5 treatment was almost four times that of the control group and moreover Se did not translocate to roots and consequently to soil. Foliar spraying with 0.5 mg Se $L^{-1}$ may therefore result in functional food for humans. The results from studies with buckwheat suggest that foliar application of Se is a highly appropriate method for enrichment of different species of buckwheat with Se [24, 25].

Distribution of Se per individual plant part of Tartary buckwheat is similar for all treatments, as well as for the control. The distribution of Se in various parts of the plant differs according to species, its phase of development, and its physiological conditions [26]. In wheat, Se was very efficiently transported into the grains, while ryegrass accumulated Se mostly in roots [17]. Williams and Mayland [27] found that an accumulator plant transported Se to shoots more readily than a nonaccumulator. There is scarce information about translocation of Se from leaves to roots. Our results indicate that foliarly applied Se remains in leaves or is transported to the seeds, but not to roots. Results showed that treating plants with 10 mg Se $L^{-1}$ (SF 10) in this case was the most effective method for obtaining Se-enriched Tartary buckwheat for human food in terms of the content of Se. Seeds contained 185 ng Se per g of dry mass. Recommended daily intake for selenium is 30–70 $\mu$g Se per day for healthy adult Europeans [28]. One kilogram of bread (50% dry matter) from Tartary buckwheat flour (SF 10 treated), prepared according to the standard procedure (50% buckwheat and 50% wheat flour), contains about 46 $\mu$g of Se. A serving of bread (100 g), in that case, contains 4.5 $\mu$g of Se. That covers 6.5%–15% of the daily requirement for this element. According to studies on other plants [24, 25], foliar spraying with the same concentration (10 mg Se $L^{-1}$) of Se would be more efficient in terms of Se accumulation in buckwheat and safer for the environment compared to soil fertilization, but concentration of Se in edible parts of that buckwheat was much too high for human consumption.

## 4. Conclusions

Different applied treatments of plants with Se were safe in terms of the use of Tartary buckwheat in human diets, but the most effective studied treatment in terms of functional food production was soil fertilization with 10 mg Se $L^{-1}$. Tartary buckwheat as an exotic semiwild plant, characterized by high concentrations of the flavonoid rutin in leaves and grain, could be applicable for use as a functional food, enriched with Se. It is therefore possible to use Tartary buckwheat, a food rich in flavonoids, as an important nutritional source of Se as well.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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