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Analysis of essential macro-micro mineral content of twelve hosta taxa

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A B S T R A C T

Hosta is a perennial ornamental herb, sometimes consumed as a vegetable in Japan. We evaluated the leaf mineral content of twelve hosta plant taxa, namely *Hosta sieboldiana*, *H. alismifolia*, *H. sieboldii*, *H. longissima*, *H. tardiva*, *H. longipes* var. *gracillima*, *H. nakaiana*, *H. kikutii* var. *caput-avis*, *H. kikutii* var. *polyneuron*, *H. longipes* var. *caduca*, *H. kiyosumiensis*, and *H. montana*. The leaf K content of 12 hosta plant taxa ranged from 2.85 to 4.05%; the P content from 0.13 to 0.34%; Ca from 0.02 to 1.15%; Mg from 540.00 to 794.12 ppm; Mn 26.93 to 133.77 ppm; Zn 115.39 to 334.52 ppm; Cu 1.78 to 5.95 ppm and Fe 26.43 to 251.95 ppm. Our results indicate that *H. alismifolia* is the best source of K; *H. sieboldii* the best sources of Ca and Fe; *H. nakaiana* of P, Mg and Zn; and *H. longissima* of Mg and Cu. The K content value for *H. montana* was statistically identical to that for *H. alismifolia*. The Cu content values for *H. montana* and *H. nakaiana* were statically identical to that for *H. longissima*. *H. alismifolia*, *H. sieboldii*, *H. longissima*, *H. nakaiana*, and *H. montana* were found to be richer in the minerals studied than the other species studied here.

Introduction

Vegetables are a main dietary component worldwide, and are essential to a balanced human diet. Annuals and biennials are the most numerous vegetable types, and very few vegetables are perennials. Recently an unusual perennial vegetable, known variously as *urui* or *giboshi,* has been found in public markets in Shikoku Island, Shizuoka Prefecture and Yamagata Prefecture in Japan. In fact this plant is hosta or plantain lily. The young leaves, leaf petioles, whole leaves and shoots of hostas are edible. *H. montana* and *H. sieboldii*, vegetables consumed in Japan, have until recently been considered wild vegetables. Mineral enrichment of food crops is now a high priority in agricultural research. Despite massive improvements in crop yield through breeding, malnutrition persists. In 2012 more than 800 million people were undernourished (FAO, 2012). Diet diversification is one of the best ways to combat malnutrition (Bhutta et al., 2008; Negin et al., 2009). Rural or tribal people in developing countries harvest a large number of wild vegetables from non-cultivated areas to overcome food deficiency and to achieve taste novelty (Afolayan and Jimoh, 2009). A similar pattern is observed in industrialized countries such as Japan. Micronutrient deficiency can easily be overcome by the consumption of green leafy (micronutrient enriched) vegetables (Saikia and Deka, 2013; Ebert, 2014; Gibson, 1994). Though wild species are rich in macro- and micronutrients, lack of nutritional information frequently gives rise to absence of wild vegetables in the diet (Dansi et al., 2008) and insufficient consumption of health protecting nutrients (Odhav et al., 2007). The nutritional composition of various edible wild species has been evaluated worldwide, especially in developing and underdeveloped countries (Edeoga et al., 2006; Ekop, 2007). Hosta, a member of the Asparagaceae family, is similar to asparagus (a perennial vegetable). Hostas have the potential for common use like asparagus. It is difficult to include wild species in the everyday intake of edible plants in industrialized countries such as Japan. However, given current nutritional concerns, wild vegetables are becoming commercial crops in industrialized countries. Japanese people have already started using hosta as a vegetable, though that utilization is as yet limited with a little scientific information about the nutritive status of hosta. In that light, the main objective of this study is to evaluate the macro- and micro- minerals in the leaves of the hosta species available in Japan.

Materials and methods

Our laboratory collected samples of hosta plant taxa from the hills and riverside areas, and also from individual hosta growers

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who have been cultivating hosta for more than 5 years, since they first collected samples from nearby hills and riversides. For our analysis of macro and micro mineral content, we selected plants from among those collected from individual hosta growers. The experiment was conducted at the Laboratory of Vegetable and Floricultural Science, Faculty of Agriculture, Kochi University, Japan.

Plant leaf collection

We planted rhizomes of *H. sieboldiana, H. alismifolia, H. sieboldii, H. longissima, H. tardiva, H. longipes var. gracillima, H. nakaiana, H. kikutii var. caput-avis, H. kikutii var. polyneuron, H. longipes var. caduca, H. kiyosumiensis, H. montana* plants in pots in February 2015 and cultivated them in open condition for one year at Kochi University, Japan. After that, we again transferred the rhizomes into new pots to emerge new leaves. Nursery earth® (Takii & Co. Ltd., Kyoto, Japan) were used in the pots for hosta cultivation. The Nursery earth is a year-round pot soil used for raising seedlings, supplemented with 320 mg/L N; 210 mg/L P and 300 mg/L K fertilizer with mild acidity. No additional fertilizers or other ingredients were used with this soil. Each taxon was grown in 4 pots, for a total of 48 pots for twelve taxa.

Sample preparation and analysis

Unfurled leaves (petioles were avoided) from newly emerged plants were collected, washed in tap water and rinsed in distilled water to remove all dirt. After the plants were washed, the leaf surface water was removed by air drying. The leaf samples were dried in an oven and the dried leaves were powdered. An electric blender was used to prepare the powder. After the powdering of each sample, the electric blender was cleaned thoroughly (chronologically by vacuum cleaner, 70% ethanol and dried by eclectic drier). The powder was then transferred into desiccators for 6 h to eliminate moisture. We followed the procedures described by Ikeda (1980) for sample preparation and acid digestion. 2.0 g of powder were used for ashing in a Phoenix™ CEM microwave muffle furnace (Tokyo, Japan) at 580 °C for 6 h. The samples were left to cool in the furnace for 5–6 h. Approximately 5 ml HCl: H_2O_2 (1:1) solution were added to the ash then heated at 80 °C temperature to reduce the volume to approx. 1–2 ml. We sealed each of the vessels to avoid possible contaminations and losses. The solution was filtered using 5B ash-free filter paper, and made the volume exactly 100 ml using de-ionized water. From the 100 ml solution, 1000 μl of solution was taken in sample vials and diluted in ion exchanged water for a final volume of 50 ml. Diluted 50 ml solutions were used for the inorganic analysis. De-ionized water was used for dilution of HNO_3 and the diluted HNO_3 was used as sample blanks. The blank sample was run at the same time as the sample being analyzed. We subtracted the values of sample blanks from the value of the analyzed sample. We used NIST1570a trace elements in spinach leaves and NIST1573a tomato leaves (only for Fe) (Sigma-Aldrich Co. LLC, Tokyo, Japan) to verify the accuracy of the procedures. We determined mineral content of the samples using Induced Coupled Plasma Spectroscopy (Japan) fitted with an automatic sampler (Japan) for macro minerals (K, P, Ca and Mg) and micro minerals (Fe, Zn, Mn and Cu).

Calculations

The absorption values were calculated based on the comparison of absorption in standard samples with known concentration and converted into ppm. We calculated total ppm using the following formulas.

dilution factor = final volume/initial volume
ppm from curve = (absorbance × 10)/slope of calibration
total ppm = [ppm from curve × volume (ml) × dilution factor]/ sample dry weight in g]

Here, the dilution factor was 50 and the volume was 100 ml. Due to the high ppm values for K, P and Ca, we converted the ppm values for these three nutrients to percentages.

Statistical analysis

The experimental data are represented as mean ± standard deviation (SD). Significant differences were determined by means of Tukey's HSD test ($P < 0.01$).

Results

Macro and micro minerals content on the leaves of twelve hosta taxa are presented in Table 1. *H. alismifolia* had higher K (4.05%) content than the other species. *H. montana* had 3.87% K content, whereas that of *H. sieboldii* was significantly lower (3.23%). *H. nakaiana* had the greater P content (0.34%) than other hosta taxa. The second topmost P content was observed in *H. tarvida* (0.29%). *H. montana* and *H. sieboldii* showed 0.23% and 0.21% of P, respectively. Significantly higher Ca content was noticed in *H. sieboldii* (1.15%), but *H. montana* contained very low Ca (0.17%). *H. nakaiana* (794.12 ppm) was found to have the highest Mg content, was followed by *H. alismifolia* (767.37 ppm). The Mg content in the leaves of *H. montana* and *H. sieboldii* was 606.68 ppm and 603.95 ppm respectively. We found significantly more Mn in *H. longissima* leaves (133.77 ppm) than in other taxa. The highest Zn content was in *H. nakaiana* (334.52 ppm) leaves, followed by *H. longissima* (322.08 ppm), *H. montana* (294.92 ppm) and *H. alismifolia* (284.78 ppm). The highest Cu content was noted in *H. longissima* (5.95 ppm) which was statistically identical with *H. nakaiana* (5.62 ppm) and *H. montana* (5.52 ppm). The Fe content of the other species was much lower than that of *H. sieboldii* (251.95 ppm) and *H. alismifolia* (206.41 ppm).

Discussion

Wild leafy vegetables contain higher macro and micro minerals than commercial vegetables (Pradeepkumar et al., 2013). We found a significant difference among hosta species in terms of content of macro minerals K, P, Ca, Mg and micro minerals Fe, Zn, Mn, Cu (Table 1). *H. montana* and *H. sieboldii* are commonly found in Japanese public markets. No significant difference in K content was found between *H. alismifolia* and *H. montana*. STFC-2015 (The Standard tables of food composition in Japan - 2015) reported that the K content was maximum in the fresh taro 10%, Japanese royal fern 2.2%, Japanese radishes 3.5%, bracken fern 3.2% while hosta leaves had similar ranges of the K (2.85–4.05%). Hosta plant leaves have higher K and P content than that of the other leafy vegetables (Caunii et al., 2010; Aletor et al., 2002). A different level of Ca content was found from dissimilar studies (Caunii et al., 2010; Saikia and Deka, 2013). The fresh sesame seeds and taro had the maximum 1.2% Ca according to STFC-2015. We found one species (*H. sieboldii*) among the studied 12 species containing 1.15% of Ca, higher than STFC-2015, Japan and all levels found in other studies conducted in different countries for various wild edible plants. Data from our study indicated that *H. sieboldii* could be an excellent daily diet source of Ca. It appears that Japanese people used to consume this species as a source of calciums. The results of this study indicate that hosta taxa are a good source of Mg and Mn. Various studies have examined the Mn, Mg, Zn, Cu and Fe content of wild

Table 1
Macro and micro minerals content on the leaves of twelve hosta taxa.

Hosta taxa	K (%) ± SD	P (%) ± SD	Ca (%) ± SD	Mg (ppm) ± SD	Mn (ppm) ± SD	Zn (ppm) ± SD	Cu (ppm) ± SD	Fe (ppm) ± SD
H. longissima	3.61 ± 0.025^{c}	0.23 ± 0.006^{e}	0.12 ± 0.007^{d}	658.93 ± 11.92^{c}	133.77 ± 8.13^{a}	322.08 ± 6.72^{b}	5.95 ± 1.13^{a}	65.02 ± 1.76^{d}
H. sieboldiana	3.87 ± 0.019^{b}	0.26 ± 0.005^{d}	0.16 ± 0.003^{c}	540.00 ± 8.80^{i}	60.18 ± 5.97^{b}	186.51 ± 7.38 k	4.12 ± 1.03 c^{d}	31.55 ± 1.73 g
H. kyosumiensis	3.43 ± 0.069^{c}	0.13 ± 0.004 j	0.08 ± 0.003 j	650.14 ± 9.22^{d}	37.94 ± 9.45 f^{g}	115.39 ± 6.93 l	2.70 ± 1.22^{ef}	39.29 ± 1.97^{f}
H. montana	$3.87 \pm 0.030a^{b}$	0.23 ± 0.005^{e}	0.17 ± 0.005^{b}	606.68 ± 7.42^{f}	44.71 ± 9.34^{de}	294.92 ± 6.71^{c}	5.52 ± 1.08^{ab}	40.23 ± 1.47^{f}
H. alismifolia	4.05 ± 0.018^{a}	0.27 ± 0.005^{c}	0.09 ± 0.005^{i}	767.37 ± 8.69^{b}	33.75 ± 8.83 g^{h}	284.78 ± 8.71^{d}	4.62 ± 0.94^{bc}	206.41 ± 1.59^{b}
H. longipes var. gracillima	3.14 ± 0.018^{de}	0.20 ± 0.003 g	0.10 ± 0.001 g	561.32 ± 4.61 h	41.28 ± 7.61^{ef}	201.29 ± 8.24^{i}	3.13 ± 1.15^{de}	71.83 ± 1.78^{c}
H. tarvida	3.15 ± 0.033^{de}	0.29 ± 0.005^{b}	0.11 ± 0.007^{f}	547.11 ± 7.85^{i}	48.96 ± 7.03^{d}	237.25 ± 7.15 g	1.78 ± 1.37^{f}	30.27 ± 1.37 g^{h}
H. kikutii var polyneuron	3.52 ± 0.019^{c}	0.19 ± 0.004^{i}	0.02 ± 0.006 k	639.48 ± 6.15^{e}	28.92 ± 8.25^{hi}	271.49 ± 7.56^{e}	3.84 ± 1.20^{cde}	39.65 ± 1.87^{f}
H. longipes var. caduca	2.85 ± 0.030^{f}	0.20 ± 0.005 g	0.07 ± 0.005 j	571.98 ± 4.15 g	54.78 ± 6.10^{c}	230.50 ± 7.55 h	2.63 ± 1.23^{ef}	29.91 ± 1.23 h
H. nakaiana	3.86 ± 0.017^{b}	0.34 ± 0.003^{a}	0.11 ± 0.003^{e}	794.12 ± 4.62^{a}	48.41 ± 7.35^{d}	334.52 ± 6.78^{a}	5.62 ± 1.70^{ab}	62.16 ± 1.02^{e}
H. kikutii var caput-avis	$3.03 \pm 0.016e^{f}$	0.20 ± 0.004 h	0.10 ± 0.004 h	579.08 ± 7.64 g	26.93 ± 8.26^{i}	192.98 ± 6.05 j	$3.84c \pm 1.18^{de}$	26.43 ± 1.17^{i}
H. sieboldii	3.23 ± 0.030^{d}	0.21 ± 0.004^{f}	1.15 ± 0.006^{a}	603.95 ± 3.24^{f}	55.56 ± 8.90^{bc}	245.35 ± 6.12^{f}	4.26 ± 1.20^{bcd}	251.95 ± 1.20^{a}

Here, superscript letters in the column denote mean separation by Tukey's HSD test at 1% level of significance.
Results are expressed as, means of four replications±SD (Standard Deviation).

vegetables in a number of countries (Saha et al., 2015; Saikia and Deka, 2013; Hussain et al., 2011; Aletor et al., 2002). The Cu level found in our studied hosta species was mostly similar that found in most of the STFC-2015, Japan reported vegetables. We found the highest Zn content, 334.52 ppm, in *H. nakaiana*. The Zn content of hosta leaves was higher than other fresh vegetable reported in STFC-2015, Japan. The Zn and Fe content in the Japanese fresh vegetables had leas than 100 and 200 ppm respectively (MEXT, 2017). In particular of our data indicate that *H. sieboldii* and *H. alismifolia* are good sources of Fe, and *H. nakaiana and H. longissima* of Zn. According to STFC-2015, the minerals in green asparagus shoot were 0.27% K, 0.019% Ca, 0.06% P, 90 ppm Mg, 1.9 ppm Mn, 1.0 ppm Cu, 7 ppm Fe and 5 ppm Zn (MEXT, 2017). Hosta plant leaves contained higher minerals than that of asparagus. From the results and discussion, it is clear that hosta leaves are a very good dietary source of minerals.

Conclusion

From the results of the current study we can conclude that hostas can be used as a regular dietary source of minerals. Among the studied species, *H. alismifolia*, *H. sieboldii*, *H. nakaiana*, *H. longissima*, *H. montana* can be considered excellent sources of some minerals and can be recommended for their K, Ca, Fe, P, Mg, Zn content. However, further study is needed for proximate and vitamin analysis. Hosta leaves with high minerals could be utilized for the fulfillment of human daily mineral requirements.

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Conflict of interest

We declare that we have no conflict of interest.

Authors contribution

Hasan Mehraj conceived, designed and performed the experiments, analyzed the data and wrote this manuscript. Yasuyo Nishimura demonstrated the whole experimental process. She also contributed some of the required materials, reagents and entire lab support. Kazuhiko Shimasaki contributed the plant materials and the chemicals required. Kazuhiko Shimasaki and Yasuyo Nishimura were responsible to supervise the experiment and revise the manuscript.

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