Feasibility of Producing Selenium-Enriched Water Lettuce (*Pistia stratiotes* L.)

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**Abstract:** The feasibility of producing selenium-enriched water lettuce (*Pistia stratiotes* L.) was studied by cultivating water lettuce in Hoagland's solution containing 0, 20, 40, 60 and 80 mg Se from sodium selenite/L. There were 4 replicates in each Se concentration. Each replicate consisted of 30 plants of water lettuce. Three plants of water lettuce in each replicate were sampled on day 0, 1, 2, 3 and 4 of the experiment. The samples were washed with deionized water, separated for leaves and roots and finally dried at 65°C. Prior to Se determination, leaf or root samples were pooled by replicate. The finding revealed that Se concentrations in leaves and roots of water lettuce increased significantly (p<0.05) with increasing Se concentration in Hoagland's solution and day of cultivation. However, Se concentration in leaves was lower than that of roots. Water lettuce cultivated in the solution containing 60 to 80 mg Se L⁻¹ exhibited the yellow leaves and died in day 2 and 3. Therefore, the appropriate Se concentration and duration for producing Se-enriched water lettuce were 20 to 40 mg Se L⁻¹ and 2 to 3 days of cultivation. The leaves of water lettuce cultivated in those conditions contained 11.14-13.50 and 21.06-29.55 mg Se kg⁻¹, respectively.

**Key words:** Water lettuce, *Pistia stratiotes* L., selenium enrichment

**INTRODUCTION**

Selenium (Se) is a crucial trace element in human and animal nutrition (McDowell, 1992; Underwood and Suttle, 1999). It is an essential component of a number of enzymes like glutathione peroxidase (Arthur, 1997) and plays an important role in thyroid metabolism (Köhler et al., 2005). Furthermore, daily Se supplementation in amounts up to 200 µg can reduce colorectal and prostate cancer (Schrauzer, 2002; Kim and Mahan, 2003). An insufficient Se intake has been linked with impaired thyroid metabolism, infertility, reduced response to vital infection and in more serious situations, cardio-and skeletal-mytopathies (MacRae, 2005). Therefore, numerous studies have been concentrated on increasing Se content in animal products to improve Se status of the consumers. The outcomes of those studies revealed that organic Se in the form of Se-enriched yeast significantly increased (p<0.05) Se contents in meat of broilers (Oliveira et al., 2005), pork (Mahan and Parrett, 1996; Zhai et al., 2007), milk (Ortman and Pehrson, 1999; Knowles et al., 1999; Jumper et al., 2006; Pechova et al., 2008) and eggs (Payne et al., 2005; Skrivan et al., 2006; Pan et al., 2007) when compared with inorganic Se in the form of selenite. However, Se-enriched yeast is an expensive commercial product and its production process requires complex and high technology (Subajda et al., 2000). On the other hand, the production of Se-enriched plants is more practical (Sugihara et al., 2004; Tsuneyoshi et al., 2006). Thus, the Se-enriched plants have been extensively reported in prospect of human nutrition in broccoli sprout (Finley et al., 2001), green onions (*Allium fistulosum*) (Kapolna and Fodor, 2006), garlic (*Tuneyoshi et al., 2006*) and sprouts of several plants (Lintschinger et al., 2000; Sugihara et al., 2004). Iauku and Xiaolong (2004) produced Se-enriched malt and fed it to laying hens. Although, they found that Se from sodium selenite and Se-enriched malt insignificantly deposited in the eggs, the result showed that Se-enriched plant could be used as Se source in animal diets.

Water lettuce (*Pistia stratiotes* L.) is a free-floating freshwater macrophyte and known as one of the most important tropical aquatic weeds (Lubrada and Fornasari, 2002). It presents a high growth rate and has been successfully used for the removal of toxic metals such as mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu),...
zinc (Zn) and manganese (Mn) from pollutant water (De et al., 1985; Srirachar, 1986; Satyakala and Jamil, 1992; Miretzy et al., 2004; Skinner et al., 2007). The above reports exhibited that water lettuce has high capacity in metal absorption. Therefore, water lettuce can be possibly used to produce Se-enriched plant for animal nutrition. The objective of this study was to determine the effect of Se concentrations on Se accumulation in water lettuce.

MATERIALS AND METHODS

The experiment was conducted in October to November, 2007. Water lettuce plants were corrected from a natural pond in Maha Sarakham province located in northeastern Thailand. The collected plants were washed thoroughly and maintained with tap water in plastic containers for 5 days. Subsequently, thirty of the same size plants with an approximate diameter of 5 cm were selected and introduced into each plastic container (30×40×8 cm) containing 0, 20, 40, 60 and 80 mg Se L⁻¹ in Hoagland’s solution. Sodium selenite (Fluka, Germany) was used as the Se source. There were four replicates in each Se concentration. Three plants of water lettuce were sampled periodically at day 0, 1, 2, 3 and 4 of the experiment from each replicate. The sampled plants were washed thoroughly with deionized water, separated into leaves and roots and later dried at 65°C for 48 h. Dried individual sample of leaves and roots was ground through 1 mm screen and separately pooled by replicate before determination of Se concentration. Approximately 0.5 g of pooled samples of leaves and roots were digested in a mixture of 1 mL HNO₃ and 9 mL deionized water until the solution was cleared. The mineralises were diluted with deionized water to the final volume of 25 mL. Selenium was determined by inductively coupled plasma mass spectrometer (ICP-MS model Elan-e, Perkin-Elmer SCIEX, USA) according to Joaquin et al. (1997).

Statistical analysis: The data of Se concentrations in leaves and roots of water lettuce were in completely random design using the general linear model procedure (SAS, 1996). The differences among means of Se concentrations in leaves or roots were compared by Duncan’s New Multiple Range Test (Steel and Torries, 1989). A probability level of p<0.05 was considered to be statistically significant.

RESULTS AND DISCUSSION

The results demonstrated that Se concentrations in leaves of water lettuces increased significantly (p<0.05) with increasing Se concentration in the solution. The Se content in leaves of water lettuce cultivated in solution containing 0 mg Se L⁻¹ ranged from 0.25 to 0.48 mg L⁻¹ (Table 1). However, Se concentrations in leaves of water lettuces cultivated in solutions containing 20 and 40 mg Se L⁻¹ increased significantly (p<0.05) from day 0 to 3 and seemed to be gradually declined (p<0.05) thereafter. Selenium concentrations in leaves of water lettuces cultivated in solution containing 60 mg Se L⁻¹ increased significantly (p<0.05) from day 0 to 2, but decreased abruptly (p<0.05) in day 3.

The Se concentrations in roots of water lettuces increase significantly (p<0.05) with increasing Se concentration in the solution and exposure period (Table 2). Selenium deposition in roots was higher than that in leaves of water lettuce (Table 1). Unfortunately, there was no available scientific information of Se

<table>
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<th>Day of cultivation</th>
<th>0</th>
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<th>40</th>
<th>60</th>
<th>80</th>
<th>SEM</th>
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<td>19.76⁷</td>
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<td>2</td>
<td>0.25³</td>
<td>11.14⁹</td>
<td>21.06⁷</td>
<td>43.04⁷</td>
<td>#</td>
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<tr>
<td>3</td>
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<td>13.50⁹</td>
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<td>3.61</td>
</tr>
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<td>13.71⁷</td>
<td>26.48⁷</td>
<td>#</td>
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</table>

⁸,⁹ Values in row with different superscripts are significantly different at p<0.05. Values in column with different superscripts are significantly different at p<0.05. # Water lettuce died

<table>
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<th>Day of cultivation</th>
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<th>60</th>
<th>80</th>
<th>SEM</th>
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<td>0.58⁹</td>
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<td>94.60⁹</td>
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</tr>
</tbody>
</table>

⁸,⁹ Values in row with different superscripts are significantly different at p<0.05. Values in column with different superscripts are significantly different at p<0.05. # Water lettuce died
deposition in water lettuce. However, the previous studies similarly observed Cr and Hg accumulations in roots of water lettuce was 3 to 5-folds (Satyakala and Jamil, 1992) and 4-folds (De et al., 1985) higher than that in leaves, respectively. Additionally, Fargasova (2004) reported Se accumulation was higher in the roots than in the cotyledon of Simapis alba L. Roots of aquatic plants naturally submerged in the water. It was therefore the first part of plant to accumulate minerals (Skinner et al., 2007). The translocation of metals from roots to shoots generally was very low. Xiong (1998) observed about 90% of lead (Pb) taken up remained in the underground parts of plants. Similarly, Fargasova (2004) mentioned that translocation of Se to aboveground plant parts was probably slow. Because Se is transported predominantly in the xylem and presumably the greater leaf surface area contributed to a relatively higher transpiration rate and increased movement of Se to the transpiring leaves of plants (Bamuolas et al., 1997).

Selenium accumulation in water lettuce increased rapidly from the first day of cultivation. Selenium concentrations in leaves and roots on day 1 increased 58.88 to 219.55-folds and 58.13 to 327.65-folds, respectively, as compared with those on day 0. However, Se concentrations in leaves and roots increased (0.73 to 3.06-folds) in a declining rate from day 2 to 4. The above results indicated that water lettuce greatly absorbed and accumulated Se in the first 24 h of cultivation. The foregoing findings similarly found that higher than 85% of Hg (De et al., 1985), Pb, Cr, Mn and Zn (Mirecky et al., 2004) in the water were absorbed by water lettuce within 24 h. The rate of the metal uptake process was dependent on the metal concentration in plants (Mirecky et al., 2004). Thus, the decreasing rate of Se absorption was probably due to higher Se concentration in water lettuce and the decreased mineral concentration in the water (Attioru, 1976).

Toxic metal accumulation produced significant physiological and biochemical responses (Phalson, 1989). Water lettuce cultivated in solution containing 60 and 80 mg Se L\(^{-1}\) showed partly yellowing of leaves and died within 3 and 2 days, respectively. However, water lettuce showed yellowing of leaves in day 4 when it was cultivated in the solution containing 40 mg Se L\(^{-1}\). The yellowing of leaves was previously found in water lettuce cultivated in the solution containing 20 mg L\(^{-1}\) of Hg (De et al., 1985) and 25 to 50 mg L\(^{-1}\) of Cr (Satyakala and Jamil, 1992). Furthermore, the roots of the dead water lettuce appeared to reduce in length. An excess of Se in plant can adversely affect chlorophyll content (Fargasova, 2004) and morphology of roots (Hartikainen et al., 2001; Fargasova, 2004). Se toxicity inhibited severely the production of chlorophyll (Fargasova, 2004). Subsequently, the yellowing of leaves or chlorosis in water lettuce occurred in the present study. The restricted root elongation of water lettuce might be caused by the damage of the root plasma membrane during Se penetration into the root cells (Fargasova, 2004). The obtained results demonstrated that water lettuce could tolerate Se concentration approximately 20 to 40 mg L\(^{-1}\).

Absorbed Se will be converted metabolically in chloroplast to selenoprotein, predominantly in the form of selenomethionine, which is a component of protein in tissues of plants (Leustek and Saito, 1999; Tinggi, 2003). Thus, the suitable plants for Se-enriched plant production should contain high protein, absorb and accumulate Se markedly and convert effectively inorganic Se to organic Se. Water lettuce contained 15 to 35% of protein, mostly in leaves (Rao and Reddy, 1984; Henry-Silva and Camargo, 2006). It is possibly used for Se-enriched production. The current results of Se accumulation, Se tolerant concentration and duration indicated that the appropriate Se concentration and duration for producing Se-enriched water lettuce were 20 to 40 mg Se L\(^{-1}\) and 2 to 3 days, respectively. Selenium concentrations in leaves of water lettuce cultivated in the solution containing 20 and 40 mg Se L\(^{-1}\) were 11.14 to 13.50 and 21.06 to 29.55 mg kg\(^{-1}\), respectively. The productions of Se-enriched plants have been extensively studied in several edible plants. Kapolka and Fodor (2006) reported total Se concentration in green onions (Allium fistulosum) reached the 61.8 mg kg\(^{-1}\) level when applying selenite at a concentration of 100 mg L\(^{-1}\) as Se source. Finley et al. (2001) produced high-Se broccoli sprout contained 62.3 mg Se kg\(^{-1}\) using selenate at a concentration of 25 mg L\(^{-1}\) as Se source. The Se concentration of Se-enriched malt was 60.5 mg kg\(^{-1}\) when treated with water containing 90 mg Se L\(^{-1}\) of selenite (Jiaxiu and Xiaolong, 2004). The Se concentrations in Se-enriched plants previously reported were higher than that found in water lettuce in this study. Therefore, further study for producing Se-enriched water lettuce should focus on factors affecting Se absorption and accumulation such as levels and sources of Se, age of water lettuce and the efficiency of conversion of inorganic Se to organic Se.

**CONCLUSIONS**

Selenium concentrations in leaves and roots of water lettuce increased significantly (p<0.05) with increasing Se concentration in the solution and exposure period. The
suitable Se level and duration for producing Se-enriched water lettuce were 20 to 40 mg Se L\(^{-1}\) and 2 to 3 days, respectively. Selenium concentrations in leaves of water lettuce cultivated in those conditions contained 11.14 to 29.55 mg Se kg\(^{-1}\).

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REFERENCES


