Heavy metals composition of foods is of immense interest because of its essential or toxic nature. This study examines concentrations of some heavy metals (Fe, Cu, Zn, Mn, Pb, Ni and Cd) from sixteen potato cultivars grown at Erzurum, Turkey. The present study revealed that the potato cultivars studied showed a considerable variation in heavy metal concentrations. The contents of heavy metals in the potato cultivars were found in the ranges: 48.87-72.64 mg kg⁻¹ for iron, 3.07-5.43 mg kg⁻¹ for copper, 13.80-18.89 mg kg⁻¹ for zinc, 6.93-13.06 mg kg⁻¹ for manganese, 0.51-0.77 mg kg⁻¹ for lead, 2.02-3.55 mg kg⁻¹ for nickel and 0.08-0.32 mg kg⁻¹ for cadmium. The accumulation pattern for the metals in the potato tubers was in the order; Fe>Zn>Mn>Cu>Ni>Pb>Cd.

**Keywords:** *Solanum tuberosum* L., potato tuber, heavy metals, concentration.

**INTRODUCTION**

The potato is the world’s fourth largest food crop and is a staple in many diets around the world. In addition to being a source of highly digestible carbohydrate and nutritionally complete protein, the potato is also an excellent source of other essential nutrients (Suttle, 2008).

In recent years, increasing attention has focused on heavy metal concentrations of vegetables all over the world. Heavy metals have important positive and negative roles in human life (Adriano, 1984; Slaveska et al., 1998; Divrikli et al., 2003; Dundar and Saglam, 2004; Colak et al., 2005; Oktem et al., 2005). Metals such as lead, mercury, cadmium, and copper are cumulative poisons, which cause environmental hazards and are reported to be exceptionally toxic (Ellen et al., 1990). Metals like iron, copper, zinc and manganese are essential metals for humans, since they play an important role in biological systems, but the essential heavy metals can produce toxic effects when their intake is excessively elevated (Schroeder, 1973; Mendel et al., 2005; Narin et al., 2005). Hence, the trace heavy metal content in potato is an important consideration.

Heavy metal concentrations of plants is directly associated with their concentrations in soils, but their levels significantly differ with plant species, and even can also affected by genotypes within the same species (Kabata-Pendias and Pendias, 2001). From this point of view, it can be concluded that potato genotypes also will differ in heavy metal concentrations. This information may be useful for designing future breeding efforts to improve potato quality management. Little information on the magnitude of variation in heavy metal content of potato genotypes is currently available in literature and more data would benefit future nutritional studies.

In the current study, the levels of iron, copper, zinc, manganese lead, nickel and cadmium were determined in selected potato varieties.

**MATERIALS AND METHODS**

This study was conducted in 2006 at the Agricultural Research and Extension Center of Ataturk University located at Erzurum, Turkey. Previous crop at this site was wheat (*Triticum aestivum* L.). Surface soil samples (0–0.30 m) were taken at experimental site before planting. The soil was a clay-loamy, pH 7.5, low in organic matter (1.24%), rich in available phosphorus and potassium (16.6 kg da⁻¹ ve 175.9 kg da⁻¹). Mean temperatures during the growing season ranged from 11.4 to 22.6 and the relative moisture varied from 50.9 to 67.3%. The highest temperature was recorded in August and the highest relative moisture recorded in May. The total rainfall for the growing season was 114.2 mm. The highest rainfall (41.6 mm) fell in May.

The experimental design was the randomized complete block design with three replicates. Sixteen potato cultivars. Marabel (early), Fianna (intermediate), Cosmos (intermediate), L.Nigetta, Ardenta (early to intermediate), Arinda (early), Santa (intermediate to late, intermediate, early to intermediate, early), Agria (late, intermediate to late, intermediate), Famosa (late, intermediate), Quinta (intermediate), Binella (intermediate, very early to early), Marfona (intermediate, early to intermediate), Morene (late, intermediate), Granola (intermediate to late, intermediate), Monaliza (early to intermediate), Vangogh
(intermediate to late) were used in the present study. Plot size was 2.8 by 7.0 m with four rows per plots. Row spacing was 70 x 35 cm. Nitrogen (ammonium sulphate), phosphorus (triple super phosphate) and potassium (potassium sulphate) fertilizers were applied broadcast at a rate of 100 kg N ha⁻¹, 100 kg P ha⁻¹, and 50 kg K₂O ha⁻¹, respectively, and incorporated into soil before planting. Planting was done by hand on May 10. Weeds were controlled by hand weeding. Plots were irrigated as and when needed. Tubers were harvested on September 28, 2006. At harvest, two samples of five consecutive plants each were collected from an area of 4.9 m² from the middle two rows.

The tuber samples were dried at 105 °C for 24 hour, ground to pass 1 mm, and stored until analysis for heavy metals (Fe, Cu, Zn, Mn, Pb, Ni and Cd). A Perkin-Elmer Analyst 700 atomic absorption spectrometer with deuterium background corrector was used in this study. The operating parameters for working elements were set as recommended by the manufacturer. Pb, Ni, Cd, Cu in potato tubers were determined by HGA graphite furnace using argon as inert gas. The other elements were determined by using air-acetylene flame. Berghof Speedwave microwave digestion (MWS-3+) system was used. All reagents used in the present work were of analytical reagent grade unless otherwise stated. Deionised water (Millipore-Q Gradient) was used for all dilutions. All the plastic and glassware were cleaned by soaking in dilute HNO₃ (1 + 9) and were rinsed with distilled water prior to use. The standard solutions of analytes used for calibration were produced by diluting a stock solution of 1000 mg/l of the given element supplied by Sigma–Aldrich (St Louis, MO, USA). 300-500 mg of sample was digested with 8 ml of concentrated HNO₃ (65%) (Suprapure, Merck) and 2 ml of concentrated H₂O₂ (30%) (Suprapure, Merck) in microwave digestion system and diluted to 30 ml with double deionized water (Millipore-Q Gradient).

Statistical analysis was done using PROC ANOVA (SAS Inst., 1998) with mean separation by Fisher's protected LSD.

RESULTS AND DISCUSSION

Fe Concentration: Of all the micronutrients, iron is required by plants in the largest amount. Fe concentrations of the cultivars investigated significantly differed (p<0.01) (Table 1). The iron contents of the potato cultivars ranged from 48.87 to 72.64 mg kg⁻¹. Quinta was the least Fe containing cultivar, while Binella was the most Fe containing cultivar (Fig. 1).

Cu Concentration: Copper is one of the essential micronutrients, and its adequate supply for growing plants should be ensured through artificial or organic fertilizers (Itanna, 2002). Cu occurs in the compounds with no known functions as well as enzymes having vital function in plant metabolism (Kabata-Pendas and Pendas, 2001)

As can be seen in the Table 1, the average Cu concentrations significantly differed among the potato cultivars (p<0.01). Fianna had the highest Cu concentration (5.43 mg kg⁻¹), followed by Morene (4.97 mg kg⁻¹). The lowest Cu value was obtained from Marabel (3.07 mg kg⁻¹) (Fig. 2).

Zn Concentration: Analysis of variance revealed that, the cultivars studied significantly differed in terms of Zn concentration (p<0.01) (Table 1). The highest Zn concentration (18.88 mg kg⁻¹) was determined in the cultivar Fianna. Among the cultivars, Cosmos had the lowest Zn concentration (13.80 mg kg⁻¹) (Fig. 3).

Zinc is one of the important metals for normal growth and development in human beings. Deficiency of zinc can result from inadequate dietary intake, impaired absorption, excessive excretion or inherited defects in zinc metabolism (Colak et al., 2005; Narin et al., 2005).

Mn Concentration: Manganese activates numerous essential enzymes. Food contains trace amounts of manganese (Colak et al., 2005). In this study there were differences with regard to Mn concentration among the potato cultivars (p<0.01) (Table 1). The cultivars Vangogh and Minaliza, (13.06 and 12.19 mg kg⁻¹, respectively), were the cultivars having the highest Mn concentrations. In contrast, the lowest Mn values were detected in the cultivars Fianna’s (6.93 mg kg⁻¹), Cosmos (7.20 mg kg⁻¹) and Ardenta (7.44 mg kg⁻¹), respectively (Fig. 4).

Pb Concentration: Significant differences were observed among the potato cultivars for Pb (Table-1). The mean Pb concentrations varied between 0.77 mg kg⁻¹, obtained for the cultivar Binella, to 0.51 mg kg⁻¹, found for the cultivar Agría (Fig. 5).

Ni Concentration: Nickel plays some roles in body functions including enzyme functions. In very trace amounts it may be beneficial to activate some systems, but its toxicity at higher levels is more enzyme prominent (Onianwa et al., 2000). Significant differences (p<0.05) were found among the mean concentrations of the sixteen cultivars for Ni (Table 1). The Ni concentrations of the potato cultivars ranged from 2.02 to 3.55 mg kg⁻¹. The highest Ni containing cultivars were Santa, Marabel and Binella, respectively (Fig. 6).

Cd Concentration: Cadmium is a nonessential element in foods and natural waters, and it accumulates principally in the kidneys and liver. Cadmium in foods is mostly derived from various sources of environmental contamination (Adriano, 1984). Among the cultivars,
Santa presented the highest mean concentration (0.32 mg kg\(^{-1}\)) for Cd. In contrast, Morene had the lowest Cd concentration, with 0.08 mg kg\(^{-1}\) (Fig. 7). The differences among the cultivars tested were significant (p<0.01) (Table 1).

Potato cultivars have been shown to differ in their ability to accumulate Cd, although the differences between cultivars are not consistent. Harris et al. (1981), found no differences in tuber Cd concentration of cultivars. Mclaughlin et al. (1997), however, found that cultivars grown commercially exhibited significant differences in tuber Cd concentration.

Averaged over the sixteen potato genotypes, the metal accumulation pattern for the potato tubers was in following order; Fe>Zn>Mn>Cu>Ni>Pb>Cd. Similar accumulation trend was also observed by Mendil et al. (2005).

Table 1. The results of analysis of variance for some heavy metal concentrations in potato genotypes grown in Erzurum, Turkey.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Fe (Mean square)</th>
<th>Cu (Mean square)</th>
<th>Zn (Mean square)</th>
<th>Mn (Mean square)</th>
<th>Pb (Mean square)</th>
<th>Ni (Mean square)</th>
<th>Cd (Mean square)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>15</td>
<td>179.378**</td>
<td>1.069*</td>
<td>4.956 **</td>
<td>9.905**</td>
<td>0.010**</td>
<td>0.593*</td>
<td>0.010**</td>
</tr>
<tr>
<td>Error</td>
<td>32</td>
<td>27.107</td>
<td>0.477</td>
<td>2.937</td>
<td>0.461</td>
<td>0.002</td>
<td>0.222</td>
<td>0.001</td>
</tr>
<tr>
<td>LSD</td>
<td>8.199</td>
<td>16.969</td>
<td>2.858</td>
<td>1.132</td>
<td>0.909</td>
<td>0.786</td>
<td>0.038</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*,** significant at P < 0.05 and P < 0.01; CV = coefficient of variations, NS = not significant

**Fig. 1.** Fe concentrations in the tubers of potato genotypes.  
**Fig. 2.** Cu concentrations in the tubers of potato genotypes.  
**Fig. 3.** Zn concentrations in the tubers of potato genotypes.  
**Fig. 4.** Mn concentrations in the tubers of potato genotypes.
The present study revealed that the potato cultivars studied showed considerable variation in heavy metal concentrations. In particular, the uptake of Cd, Cu, Pb and Mb and their concentrations are mostly affected by genotypic differences (Prosb-Bialczyk and Mydlarski, 2000). Moreover, heavy metal content could also be influenced by location, soil and climate properties, and other factors (Caussy et al., 2003; Tok, 1997; White and Zasoski, 1999). In this study, it is also important to note that of the cultivars studied, Marfona, the most preferred cultivar by the local producers in this region, usually contained more heavy metal concentrations. We believe that such information can be beneficial for understanding the importance of cultivar selection in healthy nutrition and improving consumer awareness.

Excessive fertilization and irrigation water pollution may cause heavy metal pollution in potato production areas. In such cases, a useful approach may be to use the potato genotypes that accumulate less heavy metal.

Acknowledgements. The authors would like to thank Dr. Hakan OZER, Department of Field Crops, Faculty of Agriculture, Atatürk University, Turkey, for his careful review and the English writing of the manuscript.

REFERENCES


