CONCENTRATIONS OF SOME MACROELEMENTS IN POTATO TUBERS STORED AT 4°C AND 8°C

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Abstract

The objective of the investigations was to evaluate changes in concentrations of total protein (nitrogen x 6.25), phosphorus and potassium in tubers of two potato cultivars: Rywal and Saturna, as dependent on the application of herbicides (Afalon 50 WP, Azogard 50 WP, Sencor 70 WG, and Apyros 75 WG), after harvest and after 3 and 6 months of storage. Concentrations of total protein, phosphorus and potassium in potato tubers were strongly conditioned by genetic features of the cultivars. The tubers collected from the objects sprayed with the herbicides over the vegetation period contained by 3.7%, 8.1%, and by 3.5% more protein, phosphorus and potassium, respectively, than those nursed exclusively mechanically. The corresponding values in the latter case reached respectively (means for the objects with the use of herbicides) 24.4 g kg⁻¹, 660.5 mg kg⁻¹ and 5351.3 mg kg⁻¹. After 3 and 6 months of storage at 8°C, the content of nitrogen was significantly lower. Similarly, tubers stored at 4°C contained significantly less nitrogen, but not earlier than after 6 months. In contrast, concentrations of phosphorus and potassium did not change significantly over the storage of tubers in chambers with the lower temperature (4°C).

Key words: potato, protein, phosphorus, potassium, herbicides, storage.

ZAWARTOŚĆ WYBRANYCH MAKROELEMENTÓW W BULWACH ZIEMNIAKA PRZECZOWYWANYCH W TEMPERATURZE 4 I 8°C

Abstrakt

Celem badań było określenie zmian zawartości białka ogólnego (azot x 6.25), fosforu i potasu w bulwach ziemniaka odmian Rywal i Saturna w zależności od zastosowanych herbicydów (Afalon 50 WP, Azogard 50 WP, Sencor 70 WG, Apyros 75 WG), po zbiorze i po

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INTRODUCTION

Despite a wide selection of other raw products and foodstuffs on the market, potato tubers remain one of the staple elements of the Polish diet. In Poland, the intake of potatoes reaches about 120 kg per capita annually. Continues to be the source of many valuable components, such as highly nutritional protein, rich in exogenic amino acids (Mazurczyk 2005), and mineral compounds, including phosphorus and potassium (Leszczyński 2000, Kołasa 1993, Niederhauser 1993). The quality of raw potato is affected by several factors, such as agronomic practice, including weeding (Kraska 2002). Weeding is so important because competition with weeds for light and nutrients may cause lower concentration of some components in the tubers. In contrast, successful eradication of weeds promotes the yield potential of the cultivar and preserves its quality parameters (Głuska 2000). During the storage of tubers, especially at temperatures below 8°C, the content of protein and mineral compounds should not change considerably. However, in her investigations Rogozińska (1989) found losses of total protein after storage, while Pobereżyń (2005) observed some changes in phosphorus and potassium concentrations during a 6-month storage of tubers.

The objective of the investigations was to evaluate changes in protein, phosphorus and potassium concentrations in potato tubers of cv. Rywal and Saturna after harvest, and 3 and 6 months of storage as affected by herbicides used for weed control.

MATERIAL AND METHODS

Tubers of two potato cultivars from field experiments carried out in 2002-2004 at Mochelek Experimental Station of the Bydgoszcz University of Technology and Life Science, Poland, were used for the investigations. The field experiments were designed as randomized sub-blocks, where the first exper-
imental factor was the nursing treatments (plots without herbicides, treated with Afalon 50 WP, Azogard 50 WP, Sencor 70 WG, and Apyros 75 WG), while the second factor was the cultivars: the medium late potato cultivars Rywal and Saturna. Farmyard manure was used in autumn in the dose 25 t ha\(^{-1}\), while mineral fertilizers were applied in spring before the potato planting in the amounts calculated according to the needs of the plant and the soil nutrient resources: nitrogen – 120 kg N\cdot ha\(^{-1}\), phosphorus – 110 kg P\(_2\)O\(_5\)\cdot ha\(^{-1}\), and potassium – 120 kg K\(_2\)O\cdot ha\(^{-1}\). The samples were taken after the harvest and then placed in storage chambers at 4°C and 8°C and relative air humidity of 95%. After the harvest and the two storage periods the tubers were analyzed for nitrogen (calculated for protein concentration N\(_x\)6,25), phosphorus and potassium. The results were evaluated statistically using the variance analysis according to the design of the experiment. The smallest significant difference was calculated with the use of Tukey’s test.

**RESULTS AND DISCUSSION**

Owing to their nutritional value, potato tubers have an important role in human nutrition, for example they are a good supply of protein. Protein from potato tubers is very useful in anabolic processes, which means that their biological value is very high compared with soybean protein, and only slightly lower than the nutritional standard accepted for chicken egg protein (Mazurczyk 2005). The herbicides used in the experiment significantly increased the total crude protein content by 3.7% in tubers of both cultivars (mean 24.4 g kg fresh weight) in relation to tubers from the control plots (Figure 1). Similar results were reported by KLOŚNISKA-RYCIERSKA et al. (1979, 1975), KOLPAK et al. (1987), CĘGLAREK et al. (1990), BANASZEKIEWICZ (1993), and ZARZECKA et al. (2000). The accumulation of proteins is also conditioned by genetic factors (WOJA-LEŚNIEWSKA 1993). Out of the two examined cultivars, cv. Saturna, had significantly more protein than the other one, cv. Rywal (Figure 1).

The results have shown that the content of the macroelements was modified by the experimental factors. The tubers from plants sprayed with the herbicides contained significantly more phosphorus (by 8.1%) than those harvested from the plots treated mechanically (mean for the objects with herbicides was 660.5 mg\cdot kg\(^{-1}\)). A similar tendency was observed as an increased concentration of potassium in the tubers from plants weeded both mechanically and chemically versus plants treated only mechanically (mean concentration of potassium in tubers from the objects with herbicides was 5351.3 mg\cdot kg\(^{-1}\) – Figure 2. Higher content of macroelements in tubers can be explained by the fact that the plants free from weeds had better access to light, water and nutrients. CĘGLAREK, KSIĘŻAK (1992) did not find any sig-
Fig. 1. Content of protein in the fresh weight of tubers (g kg\(^{-1}\)) of the potato cultivars depending on the herbicides used:
A, B, a, b – homogenous groups (no significant difference between the same groups)
H-0 – plots without herbicide, H-1 – herbicide Afalon 50 WP, H-2 – herbicide Sencor 70 WG,
H-3 – herbicide Apyros 75 WG, H-4 – herbicide Azogard 50 WP

Fig. 2. Content of phosphorus in the fresh weight of tubers (g kg\(^{-1}\)) of the potato cultivars depending on the herbicides used

Significant changes in concentrations of phosphorus and potassium in tubers harvested from objects nursed by the mechanical and chemical method. KOŁPAK et al. (1987) noted a small tendency of increasing concentrations of phosphorus and potassium in tubers under such conditions, while ZARZECKA (1997) reported contrary results. Moreover, concentrations of phosphorus and potassium were significantly differentiated by genetic features of the cultivars (Figure 1), an observation that has also been demonstrated by MIKOS-BIELAK, SAWICKA (1999), KOLBE (1997), WOJNOWSKA et al. (2000). Significant differences among cultivars in concentrations of potassium were also reported by POBEREZNY (2005).
The content of the macroelements in tubers stored at 4°C and 8°C was significantly different for both cultivars (Table 1, 2, and 3). The cultivar Saturna accumulated more protein and less phosphorus and potassium than cv. Rywal. Similarly to the findings of Rogozińska (1989), after 3 and 6 months in storage chambers at 8°C, tubers of both cultivars contained on average less protein. However, storage in chambers at 4°C significantly decreased the protein content after 6 months. Concentrations of phosphorus and potassium increased significantly during storage at the higher temperature. A small increase of concentrations of both elements after storage was observed also by Poberežny (2005). It can be explained as a higher concentration of dry matter caused by decreasing amount of water used up by more intense life processes (transpiration, respiration) occurring during storage, especially at a higher temperature Sowa-Niedzialkowska (1999, 2000). In our study, concentration of phosphorus in potato tubers did not change during storage at 4°C, although some changes were observed after 6 months. The results showed significant correlation between the period of storage and a specific herbicide. The tubers collected from the plots treated with Azogard 50 WP after 3 month of storage contained less phosphorus than after the harvest, afterwards the concentration of this macroelement increased but was never higher than the starting value. A possible explanation can be an individual reaction of a cultivar to the active component of the herbicide (prometrin), which can be an activator of biochemical changes occurring during storage.

According to the Institute of Foodstuffs and Nourishment in Warsaw (Ziemlanski et al. 1995, Ziemlanski (Ed.) 2001, Gertig, Przyłowski 2006) the Recommended Daily Allowance for an adult human of about 70 kg equals 56 g of protein, 800 mg of phosphorus, and 3500 mg of potassium. Assuming that the losses of those elements during cooking of potato are negligible, consumption of about 300g of potatoes should cover 48.6% of the daily needs of adults for potassium, 25.1% for phosphorus 12.7% for protein (Nx6.25) (Table 4).
Table 1

Content of protein in fresh weight of tubers (g kg\(^{-1}\)) of the potato cultivars depending on the herbicides used and the storage time at the temperature of 8°C and 4°C

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Herbicides</th>
<th>After harvest</th>
<th>Time of storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>at the temperature of 8°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 months</td>
</tr>
<tr>
<td>Rywal</td>
<td>H-0</td>
<td>21.1</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td>22.1</td>
<td>21.7</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td>22.2</td>
<td>21.7</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>22.0</td>
<td>21.7</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>22.0</td>
<td>21.4</td>
</tr>
<tr>
<td>Mean</td>
<td>H-0</td>
<td>25.9</td>
<td>25.0</td>
</tr>
<tr>
<td>Saturna</td>
<td>H-1</td>
<td>26.8</td>
<td>26.0</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>26.5</td>
<td>26.0</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>26.8</td>
<td>26.2</td>
</tr>
<tr>
<td>Mean</td>
<td>H-0</td>
<td>24.2</td>
<td>26.0</td>
</tr>
<tr>
<td>Mean for cultivars</td>
<td>H-1</td>
<td>24.5</td>
<td>23.8</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td>24.5</td>
<td>23.8</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>24.3</td>
<td>23.8</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>24.4</td>
<td>23.8</td>
</tr>
<tr>
<td>Mean</td>
<td>24.2</td>
<td>23.6</td>
<td>23.1</td>
</tr>
</tbody>
</table>

LSD\(_{0.05}\) for the storage temperature:

<table>
<thead>
<tr>
<th>Herbicides used</th>
<th>8°C</th>
<th>4°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivars</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Storage time</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Herbicides x cv</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cv x Herbicides</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Storage time x cv</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cv x Storage time</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Storage time x Herbicides</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Herbicides used x Storage time</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Cultivars x Herbicides used x Storage time</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Explanations: H-0, H-1, H-2, H-3, H-4 – see Fig. 1, n.s. – non-significant difference
Table 2

Content of phosphorus in the fresh weight of tubers (mg kg⁻¹) of the potato cultivars depending on the herbicides used and the storage time at the temperature of 8°C and 4°C

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Herbicides</th>
<th>After harvest</th>
<th>Time of storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>at the temperature of 8°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 months</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Rywal</td>
<td>H-0</td>
<td>631</td>
<td>738</td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td>752</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td>683</td>
<td>686</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>640</td>
<td>642</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>707</td>
<td>676</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>H-0</td>
<td>583</td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td>594</td>
<td>631</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td>619</td>
<td>633</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>660</td>
<td>668</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>629</td>
<td>602</td>
</tr>
<tr>
<td>Saturna</td>
<td>Mean</td>
<td>H-0</td>
<td>617</td>
</tr>
<tr>
<td>Mean for</td>
<td>H-0</td>
<td>607</td>
<td>687</td>
</tr>
<tr>
<td>cultivars</td>
<td>H-1</td>
<td>673</td>
<td>691</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td>651</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>650</td>
<td>655</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>668</td>
<td>639</td>
</tr>
<tr>
<td>Mean</td>
<td>H-0</td>
<td>650</td>
<td>666</td>
</tr>
</tbody>
</table>

LSD₄₉₈ for the storage temperature: 8°C 4°C

<table>
<thead>
<tr>
<th></th>
<th>hericides used</th>
<th>cultivars</th>
<th>storage time</th>
<th>hericides x cv</th>
<th>cv x hericides</th>
<th>storage time x cv</th>
<th>cv x storage time</th>
<th>storage time x hericides</th>
<th>hericides used x storage time</th>
<th>cultivars x hericides used x storage time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n.s.</td>
<td>60</td>
<td>26</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>9</td>
<td>27</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Explanations: H-0, H-1, H-2, H-3, H-4 – see Fig. 1, n.s. – non-significant difference
Content of potassium in the fresh weight of tubers (mg kg⁻¹) of the potato cultivars depending on the herbicides used and the storage time at the temperature of 8°C and 4°C

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Herbi-</th>
<th>After</th>
<th>Time of storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cides</td>
<td>harvest</td>
<td>at the temperature of 8°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 months</td>
</tr>
<tr>
<td>Ryval</td>
<td></td>
<td></td>
<td>1 2 3</td>
</tr>
<tr>
<td>1</td>
<td>22</td>
<td>3</td>
<td>5510</td>
</tr>
<tr>
<td></td>
<td>H-0</td>
<td></td>
<td>5640</td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td></td>
<td>5750</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td></td>
<td>5600</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td></td>
<td>5520</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>5604</td>
</tr>
<tr>
<td>Saturna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-0</td>
<td>4820</td>
<td></td>
<td>5100</td>
</tr>
<tr>
<td>H-1</td>
<td>4930</td>
<td></td>
<td>5040</td>
</tr>
<tr>
<td>H-2</td>
<td>5090</td>
<td></td>
<td>5400</td>
</tr>
<tr>
<td>H-3</td>
<td>5230</td>
<td></td>
<td>5350</td>
</tr>
<tr>
<td>H-4</td>
<td>5050</td>
<td></td>
<td>5330</td>
</tr>
<tr>
<td>Mean</td>
<td>5024</td>
<td></td>
<td>5244</td>
</tr>
<tr>
<td>Mean for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cultivars</td>
<td>H-0</td>
<td>5165</td>
<td>5395</td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td>5285</td>
<td>5455</td>
</tr>
<tr>
<td></td>
<td>H-2</td>
<td>5420</td>
<td>5830</td>
</tr>
<tr>
<td></td>
<td>H-3</td>
<td>5415</td>
<td>5520</td>
</tr>
<tr>
<td></td>
<td>H-4</td>
<td>5285</td>
<td>5675</td>
</tr>
<tr>
<td>Mean</td>
<td>5314</td>
<td></td>
<td>5575</td>
</tr>
</tbody>
</table>

LSD₀.₀⁰₅ for the storage temperature:

<table>
<thead>
<tr>
<th></th>
<th>8°C</th>
<th>4°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>herbicides used</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>cultivars</td>
<td>450</td>
<td>390</td>
</tr>
<tr>
<td>storage time</td>
<td>250</td>
<td>n.s.</td>
</tr>
<tr>
<td>herbicides × cv</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>cv × herbicides</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>storage time × cv</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>cv × storage time</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>storage time × herbicides</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>herbicides used × storage time</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>cultivars × herbicides used × storage time</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Explanations: H-0, H-1, H-2, H-3, H-4 – see Fig. 1, n.s. – non-significant difference
Table 4

Daily covering of the demand of adult man (weighing 70 kg) for proteins, phosphorus, potassium, assuming consumption of 300 g potatoes and negligible losses during culinary processing

<table>
<thead>
<tr>
<th>Date of analysis</th>
<th>Protein intake (g)</th>
<th>Phosphorus intake (mg)</th>
<th>Potassium intake (mg)</th>
<th>% covering day demand</th>
<th>Protein</th>
<th>Phosphorus</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 3 months storage at 8°C</td>
<td>7.08</td>
<td>200</td>
<td>1673</td>
<td>12.6</td>
<td>25.0</td>
<td>47.8</td>
<td></td>
</tr>
<tr>
<td>After 3 months storage at 4°C</td>
<td>7.20</td>
<td>199</td>
<td>1706</td>
<td>12.9</td>
<td>24.9</td>
<td>48.7</td>
<td></td>
</tr>
<tr>
<td>After 6 months storage at 8°C</td>
<td>6.93</td>
<td>205</td>
<td>1762</td>
<td>12.4</td>
<td>25.6</td>
<td>50.3</td>
<td></td>
</tr>
<tr>
<td>After 6 months storage at 4°C</td>
<td>7.08</td>
<td>204</td>
<td>1767</td>
<td>12.6</td>
<td>25.5</td>
<td>50.5</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSIONS

1. Herbicides applied during cultivation of potato significantly increased concentrations of total protein and phosphorus in the tubers, while a similar tendency occurred for potassium in tubers collected from the control plots.

2. Tubers of the cultivar Saturna accumulated more protein and less phosphorus and potassium than cv. Rywal, both after harvest and storage.

3. Concentration of protein in tubers of both cultivars (mean for the objects) was significantly lower after 3 and 6 month of storage at 8°C in relation to the values recorded after harvest, while the contents of phosphorus and potassium increased significantly during storage.

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