J. Elementol. 2009, 14(2): 373–382

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

Dorota Wichrowska, Tadeusz Wojdyła, Ilona Rogozińska

Chair of Storage and Processing of Plant Products
University of Technology and Life Science, Bydgoszcz

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 PRZECHOWYWANYCH 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

dr inż. Dorota Wichrowska, Chair of Storage and Processing of Plant Products, University of Technology and Life Science, Kordeckiego St. 20 b. A, 85-225 Bydgoszcz, Poland, phone: (48 52) 374 93 20; e-mail: wichrowska@utp.edu.pl;

3 i 6 miesiącach przechowywania. Zawartość białka ogólnego, fosforu i potasu w bulwach ziemniaka różnicowały istotnie uwarunkowania genetyczne odmian. Bulwy zebrane z obiektów opryskiwanych herbicydami w okresie wegetacji roślin zawierały o 3,7% więcej białka, o 8,1% fosforu, o 3,5% potasu niż bulwy roślin pielęgnowanych wyłącznie mechanicznie, dla których wartości te wynosiły odpowiednio (średnio dla obiektów opryskiwanych herbicydami): 24,4 g kg^{-1}, 660,5 mg kg^{-1} i 5351,3 mg kg^{-1}. Po 3 i po 6 miesiącach przechowywania w temp. 8°C zawartość azotu istotnie się zmniejszała. Również w bulwach przechowywanych w temp. 4°C poziom azotu istotnie się zmniejszył, lecz dopiero po 6 miesiącach. Natomiast zawartość fosforu i potasu nie zmieniała się istotnie podczas przechowywania w bulwach składowanych w komorach o niższej temperaturze (4°C).

Słowa kluczowe: ziemniak, białko, fosfor, potas, herbicydy, przechowywanie.

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, KOLASA 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 POBEREŻNY (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 Mochełek 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 $P_2O_5 \cdot ha^{-1}$, and potassium – 120 kg $K_2O \cdot ha^{-1}$. The samples were taken after the harvest and than 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 Nx6,25), 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 Kłosińska-Rycerska et al. (1979, 1975), Kołpak et al. (1987), Ceglarek et al. (1990), Banaszkiewicz (1993), and Zarzecka et al. (2000). The accumulation of proteins is also conditioned by genetic factors (Woda- 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. Ceglarek, Księżak (1992) did not find any sig-

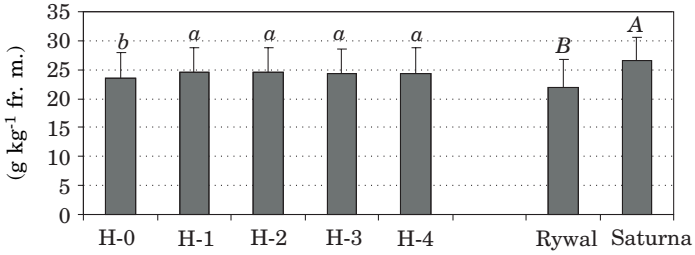
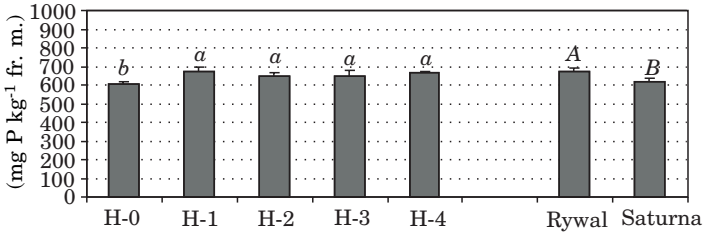
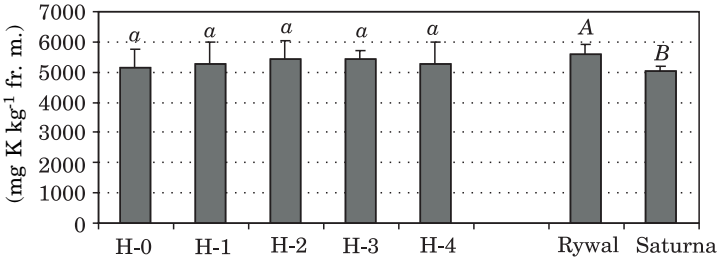


Fig. 1. Content of protein in the fresh weight of tubers (g kg^{-1}) of the potato cultivars depending on the herbicides used:
A, B, a, b – homogenous groups (no significant difference between the same groups)
H-0 – plots without herbicide, H-1 – herbicide Afalon 50 WP, H-2 – herbicide Sencor 70 WG, H-3 – herbicide Apyros 75 WG, H-4 – herbicide Azogard 50 WP



Explanation: H-0, H-1, H-2, H-3, H-4, A, B, a, b – see Fig. 1
Fig. 2. Content of phosphorus in the fresh weight of tubers (g kg^{-1}) of the potato cultivars depending on the herbicides used

nificant 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 Pobereżny (2005).



Explanations: H-0, H-1, H-2, H-3, H-4, see Fig. 1

Fig. 3. Content of potassium in the fresh weight of tubers (mg kg^{-1}) of the potato cultivars depending on the herbicides used

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 Pobereżny (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-Niedziałkowska (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, Przysławski 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 8ºC and 4ºC

Cultivars	Herbicides	After harvest	Time of storage					
			at the temperature of 8ºC			at the temperature of 4ºC		
			3 months	6 months	mean (3,4,5)	3 months	6 months	mean (3,7,8)
1	2	3	4	5	6	7	8	9
Rywal	H-0	21.1	20.5	20.0	20.5	20.7	20.5	20.8
	H-1	22.1	21.7	21.0	21.6	21.9	21.4	21.8
	H-2	22.2	21.7	21.0	21.6	21.9	21.4	21.8
	H-3	22.0	21.7	21.0	21.6	21.9	21.4	21.8
	H-4	22.0	21.4	21.0	21.5	21.7	21.4	21.7
Mean		21.9	21.4	20.7	21.3	21.7	21.2	21.6
Saturna	H-0	25.9	25.0	24.3	25.1	25.5	25.0	25.5
	H-1	26.8	26.0	25.5	26.1	26.4	26.2	26.5
	H-2	26.8	26.2	26.0	26.3	26.4	26.2	26.5
	H-3	26.5	26.0	25.7	26.1	26.2	26.0	26.2
	H-4	26.8	26.2	25.7	26.2	26.7	26.2	26.6
Mean		24.2	26.0	25.5	25.2	26.2	26.0	25.5
Mean for cultivars	H-0	23.5	22.9	22.1	22.8	23.1	22.6	23.1
	H-1	24.5	23.8	23.3	23.9	24.3	23.8	24.2
	H-2	24.5	23.8	23.6	24.0	24.3	23.8	24.2
	H-3	24.3	23.8	23.3	23.8	24.0	23.6	24.0
	H-4	24.4	23.8	23.3	23.8	24.3	23.8	24.2
Mean		24.2	23.6	23.1	23.6	24.0	23.6	23.9

$LSD_{=0.05}$ for the storage temperature:	8ºC	4ºC
herbicides used	n.s.	n.s.
cultivars	0.2	0.2
storage time	0.2	0.5
herbicides × cv	n.s.	n.s.
cv × herbicides	n.s.	n.s.
storage time × cv	n.s.	n.s.
cv × storage time	n.s.	n.s.
storage time × herbicides	n.s.	n.s.
herbicides used × storage time	n.s.	n.s.
cultivars × herbicides used × storage time	n.s.	n.s.

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 8ºC and 4ºC

Cultivars	Herbicides	After harvest	Time of storage					
			at the temperature of 8ºC			at the temperature of 4ºC		
			3 months	6 months	mean (3,4,5)	3 months	6 months	mean (3,7,8)
1	2	3	4	5	6	7	8	9
Rywal	H-0	631	738	749	706	721	718	690
	H-1	752	750	755	752	725	737	738
	H-2	683	686	687	685	697	711	697
	H-3	640	642	699	660	674	682	665
	H-4	707	676	693	692	670	676	684
Mean		683	698	717	699	697	705	695
Saturna	H-0	583	636	645	621	671	721	658
	H-1	594	631	648	624	625	636	618
	H-2	619	633	637	630	606	602	609
	H-3	660	668	695	674	631	675	655
	H-4	629	602	607	613	612	649	630
Mean		617	634	646	632	629	657	634
Mean for cultivars	H-0	607	687	697	664	696	720	674
	H-1	673	691	702	688	675	687	678
	H-2	651	660	662	658	652	657	653
	H-3	650	655	697	667	653	679	660
	H-4	668	639	650	652	641	663	657
Mean		650	666	682	666	663	681	665

$LSD_{\alpha=0.05}$ for the storage temperature:	8ºC	4ºC
herbicides used	n.s.	n.s.
cultivars	60	37
storage time	26	n.s.
herbicides × cv	n.s.	n.s.
cv × herbicides	n.s.	n.s.
storage time × cv	n.s.	n.s.
cv × storage time	n.s.	n.s.
storage time × herbicides	11	27
herbicides used × storage time	12	9
cultivars × herbicides used × storage time	n.s.	n.s.

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

Table 3

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 8ºC and 4ºC

Cultivars	Herbicides	After harvest	Time of storage					
			at the temperature of 8ºC			at the temperature of 4ºC		
			3 months	6 months	mean (3,4,5)	3 months	6 months	mean (3,7,8)
1	22	3	4	5	6	7	8	9
Rywal	H-0	5510	5690	5870	5690	5600	5640	5583
	H-1	5640	5870	6200	5903	5650	5810	5700
	H-2	5750	6260	6420	6143	5690	5990	5810
	H-3	5600	5690	6100	5797	5830	6010	5813
	H-4	5520	6020	6190	5910	6560	6580	6220
Mean		5604	5906	6156	5889	5866	6006	5825
Saturna	H-0	4820	5100	5500	5140	5440	6070	5443
	H-1	4930	5040	5740	5237	5550	5830	5437
	H-2	5090	5400	5550	5347	5180	5520	5263
	H-3	5230	5350	5610	5397	6050	5870	5717
	H-4	5050	5330	5540	5307	5310	5580	5313
Mean		5024	5244	5588	5285	5506	5774	5435
Mean for cultivars	H-0	5165	5395	5685	5415	5520	5855	5513
	H-1	5285	5455	5970	5570	5600	5820	5568
	H-2	5420	5830	5985	5745	5435	5755	5537
	H-3	5415	5520	5855	5597	5940	5940	5765
	H-4	5285	5675	5865	5608	5935	6080	5767
Mean		5314	5575	5872	5587	5686	5890	5630

$LSD_{=0.05}$ for the storage temperature:	8ºC	4ºC
herbicides used	n.s.	n.s.
cultivars	450	390
storage time	250	n.s.
herbicides × cv	n.s.	n.s.
cv × herbicides	n.s.	n.s.
storage time × cv	n.s.	n.s.
cv × storage time	n.s.	n.s.
storage time × herbicides	n.s.	n.s.
herbicides used × storage time	n.s.	n.s.
cultivars × herbicides used × storage time	n.s.	n.s.

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

Date of analysis	Daily intake			% covering day demand		
	protein (g)	phosphorus (mg)	potassium (mg)	protein	phosphorus	potassium
After 3 months storage at 8ºC	7.08	200	1673	12.6	25.0	47.8
After 3 months storage at 4ºC	7.20	199	1706	12.9	24.9	48.7
After 6 months storage at 8ºC	6.93	205	1762	12.4	25.6	50.3
After 6 months storage at 4ºC	7.08	204	1767	12.6	25.5	50.5

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.

REFERENCES

Banaszkiewicz T. 1993. *Zachowanie się herbicydów w roślinach [Fate of herbicides in plants].* Fragm. Agronom., 1: 72-79.

Ceglarek F., Ceglarek-Jabłońska R., Dąbrowska K. 1990. *Uproszczenia w pielęgnacji ziemniaków.* Cz. II. *Wpływ sposobów pielęgnacji na niektóre składniki i cechy bulw ziemniaka [Reduced nursing of potatoes.* Part II. *Effect of nursing techniques on some components and characteristics of potato tubers].* Rocz. Nauk Rol., S. A 109: 103-116.

Ceglarek F., Księżak J. 1992. *Wpływ herbicydów do niszczenia perzu na skład chemiczny bulw ziemniaka [Effect of herbicides for eradicating of couch grass on the chemical composition of potato tubers].* Fragm. Agronom., 3 (35): 58-64.

Gertig H., Przysławski J. 2006. *Bromatologia [Bromatology].* PZWL, ss. 468.

Głuska A., 2000. *Wpływ agrotechniki na kształtowanie jakości plonu ziemniaka [Effect of agronomic practice on shaping the quality of potato yield].* Biul. Inst. Hod. Rośl., 213: 173-178.

KŁOSIŃSKA-RYCERSKA B., MĘŻYKOWSKA B. 1975. *Wpływ prometryny i 2,4-D na zawartość azotu ogólnego i białkowego w bulwie ziemniaka odmiany Epoka i Kaszubski [Effect of prometrine abd 2,4-D on total and protein nitrogen content in tubers of cv. Epoka and Kaszubski potatoes].* Biul. Inst. Ziemn., 16: 135-143.

KŁOSIŃSKA-RYCERSKA B., MĘŻYKOWSKA B. 1979. *Wpływ Camparolu, Igranu 50, Potoranu i H-180 na niektóre składniki bulw ziemniaka [Effect of Camarol, Igran 50, Potoran and H-180 on some componets of potato tubers].* Biul. Inst. Ziemn., 23: 121-130.

KOLASA K.M. 1993. *The potato and human nutrition.* Am. Potato Res., 70: 375-384.

KOLBE H. 1997. *Einflussfaktoren auf die Inhaltsstoffe der Kartoffel.* Kartoffelbau, 8: 320.

KOŁPAK R., BYSZEWSKA-WZOREK A., PŁODOWSKA J. 1987. *Wpływ herbicydów na wysokość i jakość plonu ziemniaków [Effect of herbicides on volume and quality of potato tuber yields].* Rocz. Nauk Rol., Ser. A, 106 (4): 171-183.

KRASKA P. 2002. *Wpływ sposobów uprawy, poziomów nawożenia i ochrony na wybrane cechy jakości ziemniaka [Effect of cultivation methods, fertilization levels and plant protection on some potato quality parameters].* Zesz. Probl. Post. Nauk Rol., 489: 229-237.

LESZCZYŃSKI W. 2000. *Jakość ziemniaka konsumpcyjnego [Quality of edible potato].* Żywność, 7 Supl. 4 (25): 5-27.

MAZURCZYK W. 2005. *Wartość żywieniowa ziemniaka [Nutritional value of potatoes].* Raport Rolny 43. <www.raportrolny.pl>

MIKOS-BIELAK M., SAWICKA B. 1999. *Analiza czynników modyfikujących zawartość potasu, azotu, wapnia i fosforu w bulwach ziemniaka [Analysis of factors modifying concentrations of potassium, nitrogen, calcium and phosphorus in potato tubers].* Mat. Konf. Nauk. *Ziemniak jadalny i dla przetwórstwa spożywczego – czynniki agrotechniczne i przechowalnicze warunkujące jakość.* Radzików, 23-25.02.1999, 217-220.

NIEDERHAUSER J.S. 1993. *International cooperation and the role of the potato in feeding the world.* Am. Potato Res., 70: 385-403.

POBEREŻNY J. 2006. *Jakość konsumpcyjna, technologiczna i trwałość przechowalnicza wybranych odmian ziemniaka [Consumption and technological quality, and storage time of some potato cultivars]* . ATR Bydgoszcz, Rozpr. doktorska, ss. 176.

ROGOZIŃSKA I. 1989. *Problemy przechowalnictwa i przetwórstwa ziemniaków [Problems of potato storage and processing].* Zesz. Probl. Post. Nauk Rol., 380: 225-231.

SOWA-NIEDZIAŁKOWSKA G. 1999. *Wpływ wybranych czynników na zmiany ilościowe w czasie przechowywania odmian jadalnych [Effect of some factors on quality changes during the storage of edible cultivars].* Konf. Nauk. *Ziemniak jadalny i dla przetwórstwa spożywczego – czynniki agrotechniczne i przechowalnicze warunkujące jakość.* Radzików, 23-25.02 1999, 96-98.

SOWA-NIEDZIAŁKOWSKA G. 2000. *Wpływ warunków wzrostu roślin i magazynowania bulw odmian jadalnych ziemniaka na ich trwałość przechowalniczą [Effect of conditions during plant growth and storage of tubers of edible potato cultivars on their storage life].* Biul. Inst. Hod. Rośl., 213: 225-232.