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EFFECT OF BIOELEMENTS (N, K, Mg) AND LONG-TERM STORAGE OF POTATO TUBERS ON QUANTITATIVE AND QUALITATIVE LOSSES PART II. CONTENT OF DRY MATTER AND STARCH

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Abstract

One of the top objectives of the table and food processing potato production is good tuber quality. The fact that potatoes are grown for a number of different uses makes the quality requirements high, yet also varied, both in terms of morphological traits and the chemical composition. Throughout the production cycle, potato storage is the most difficult stage of maintaining good quality of tubers. During long storage, tubers are affected by processes leading to quantitative and qualitative changes. The present three-year field experiment (2003-2005) investigated the effect of varied mineral fertilisation (N, K and Mg against a fixed P dose) applied over the plant vegetation period and the influence of storage (3 and 6 months) on the content of dry matter and starch in tubers of mid-early potato cultivars: Bila and Triada. The samples were stored in a storage chamber for 3 and 6 months (temperature +4°C, relative humidity 95%). The content of dry matter and starch was significantly affected by both the fertilisation and the storage time. With increasing N, K, Mg doses, a significant increase in the content of dry matter appeared, as compared with the control, and its highest content was reported for the fertilisation with 100 kg of nitrogen (3.5% increase), 80 kg of potassium (7.7% increase) and 100 kg of magnesium per hectare (6.2% increase). However, as for the content of starch, the doses of 100 kg of nitrogen, 160 kg of potassium and 100 kg of magnesium per hectare turned out to be the most favourable. The losses of dry matter and starch in potato tubers calculated from the balance were the highest after 6 months of storage and accounted for 8.1 and 15.4% for the magnesium experiment, 6.6 and 10.1% for the nitrogen experiment, 6.7 and 7.9% for the potassium experiment, respectively.

Key words: potato tuber, N, K, Mg fertilisation, storage, qualitative losses.

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WPŁYW BIOPIERWIASTKÓW (N, K, Mg) ORAZ DŁUGOTRWAŁEGO PRZECHOWYWANIA BULW ZIEMNIAKA NA STRATY ILOŚCIOWE JAKOŚCIOWE Cz. II. ZAWARTOŚĆ SUCHEJ MASY I SKROBI

Abstract

Jednym z nadrzędnych celów w produkcji ziemniaka jadalnego i do przetwórstwa spożywczego jest dobra jakość bulw. Wielokierunkowość użytkowania ziemniaka powoduje, że wymagania co do jego jakości są wysokie, ale też i różne, zarówno pod względem cech morfologicznych, jak i składu chemicznego. W całym cyklu produkcyjnym przechowywanie ziemniaków jest najtrudniejszym etapem utrzymania dobrej jakości bulw, ponieważ w okresie długotrwałego składowania w bulwach zachodzą procesy prowadzące do zmian ilościowych i jakościowych. W trzyletnim doświadczeniu polowym (2003-2005) badano wpływ zastosowanego w okresie wegetacji roślin zróżnicowanego nawożenia mineralnego (N, K i Mg na tle stałej dawki P) oraz przechowywania (3 i 6 miesięcy) na kształtowanie się zawartości suchej masy i skrobi w bulwach wybranych odmian ziemniaka. Do badań wybrano średnio wczesne odmiany Bila i Triada. Próby przechowywano w komorze przechowalniczej przez 3 i 6 miesięcy (temp. +4^{o}C, wilgotność względna powietrza 95%). Na zawartość suchej masy i skrobi istotny wpływ miało zarówno zastosowane nawożenia, jak i czas składowania. Pod wpływem wzrastających dawek N, K, Mg następował istotny wzrost zawartości suchej masy w stosunku do obiektu kontrolnego, a najwyższą jej zawartość uzyskano po zastosowaniu nawożenia w ilości 100 kg azotu – wzrost o 3,5%, 80 kg potasu – wzrost o 7,7% i 100 kg magnezu – wzrost o 6,2% na 1 ha. W przypadku zawartości skrobi najkorzystniejsze okazały się dawki 100 kg azotu, 160 kg potasu i 100 kg magnezu na 1 ha. Straty suchej masy i skrobi w bulwach ziemniaka wyliczone z bilansu były najwyższe po 6 miesiącach przechowywania i wynosiły odpowiednio 8,1 i 15,4% w doświadczeniu z magnezem, 6,6 i 10,1% w doświadczeniu z azotem, 6,7 i 7,9% w doświadczeniu z potasem.

Słowa kluczowe: bulwa ziemniaka, nawożenie N, K, Mg, przechowywanie, straty jakościowe.

INTRODUCTION

One of the top objectives of the table and food processing potato production is good tuber quality. As potatoes are grown for a number of different uses, the potato quality requirements are high and varied, both in terms of morphological traits and the chemical composition. From the total annual potato produce, about 95% is stored for 1 to 9 months (October through June) for a variety of use (GĄSIOROWSKA 2000, LESZCZYŃSKI 2000, LISIŃSKA 2006, SOWA-NIEDZIAŁKOWSKA 2004a). Considering the entire production cycle, potato storage is the most difficult stage of maintaining good tuber quality. Throughout long-term storage, tubers are affected by processes leading to quantitative and qualitative changes (GĄSIOROWSKA 2000, LESZCZYŃSKI 2000, SOBOL 2005). The extent of those changes depends on a number of factors, such as cultivars, agrotechnical factors during the vegetation period as well as storage room conditions. The tuber quality after storage is also affected by the potato handling method when preparing for storage, i.e. eliminating the tubers which are diseased, damaged and covered with soil. Mature, healthy and mechanically intact tubers are the only ones which demonstrate an adequate applicability for long-term storage (CZERKO 2001, LESZCZYŃSKI 2000, SOWA-NIEDZIAŁKOWSKA 2002, ZGÓRSKA, SOWA-NIEDZIAŁKOWSKA 2005).

The aim of the present research has been to determine the effect of a varied mineral fertilisation (N, K, Mg) and the storage period length (3 and 6 months) on the dry weight losses and starch.

MATERIAL AND METHODS

The field and storage experiment design is given in Part One.

Immediately after harvest and storage the following were determined in potato tubers: the content of dry matter with the drying method and the content of starch polarimetrically with the Evers method (KREŁOWSKA-KUŁAS 1993). The samples were stored for the period of 3 and 6 months (temperature +4^{o}C, relative humidity 95%). After storage the amount of losses of dry matter and starch were calculated from the balance, including real natural losses.

The 3-year research results were verified with statistical calculations using Sigma Stat software (SPSS Inc., Chicago, the U.S.), and applying Tukey's test to verify the significance of differences.

RESULTS AND DISCUSSION

Potato tubers for direct consumption and for processing should demonstrate adequate morphological, chemical and organoleptic characteristics. The chemical composition of tubers, affecting their quality, is mostly cultivar-specific, although it can be modified by the environment, both during the growth and storage (ZGÓRSKA, FRYDECKA- MAZURCZYK 1996, GĄSIOROWSKA 2000, EDWARDS et al. 2002, ZGÓRSKA, SOWA-NIEDZIAŁKOWSKA 2005, ZIMOCH-GUZOWSKA, FLIS 2006).

The present research showed that, in all the trials, the content of dry matter in tubers after harvest was significantly affected by the mineral fertiliser doses applied (Figures 1, 2, 3). With the increasing N, K, Mg doses, a significant increase in the content of dry matter was observed, as compared with the control; its highest increase was reported when applying 100 kg of nitrogen, 80 kg of potassium and 100 kg of magnesium, which coincides with the results by WSZELACZYŃSKA et al. (2007), where a significant increase in the content of dry matter in tubers occurred as a result of increasing MgO doses, and following an increase in the nitrogen dose from 60 to 120 kg ha^{-1}. Contrary results were reported by BOMBIK et al. (2007),

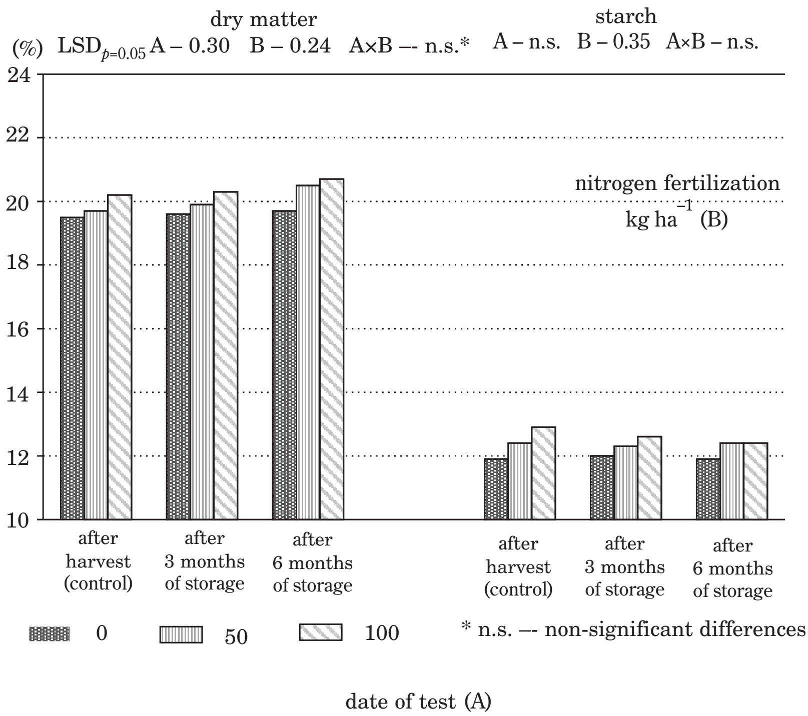

Fig. 1. The dry matter and starch content (%) in cv. Bila potato tubers depending on nitrogen fertilisation and date of test (means from 3 years)

who found out that increasing nitrogen fertilisation from 60 to 90 kg N ha^{-1} resulted in a significant decrease in the content of dry matter. According to Bombik et al. (2007), only very high nitrogen doses, the so-called over-fertilisation, can result in a decrease in the content of dry matter, which coincides with the results reported by Wszelaczyńska et al. (2007), since a further increase in the nitrogen dose from 120 to 180 kg ha^{-1} decreased the content of dry matter. The response of cultivars with respect to the content of dry matter in tubers after storage depending on the N, K, Mg fertilisation applied is the same as after harvest.

Throughout storage, tubers are affected by biochemical processes connected with respiration and germination, causing changes in the content of dry matter and starch. The extent of changes is mostly cultivar-specific but also dependent on plant fertilisation over the vegetation period and on the storage length and temperature (Bombik et al. 2007, Zimoch-Guzowska, Flis 2006, Wszelaczyńska et al. 2007). Our synthetic analysis of variance demonstrated that the content of dry matter in tubers obtained from the nitrogen and magnesium treatments (Figures 1 and 3) depended significantly on the storage duration, unlike in the potassium treatment samples (Figure 2). Interestingly, however, its significant increase, as compared with the initial

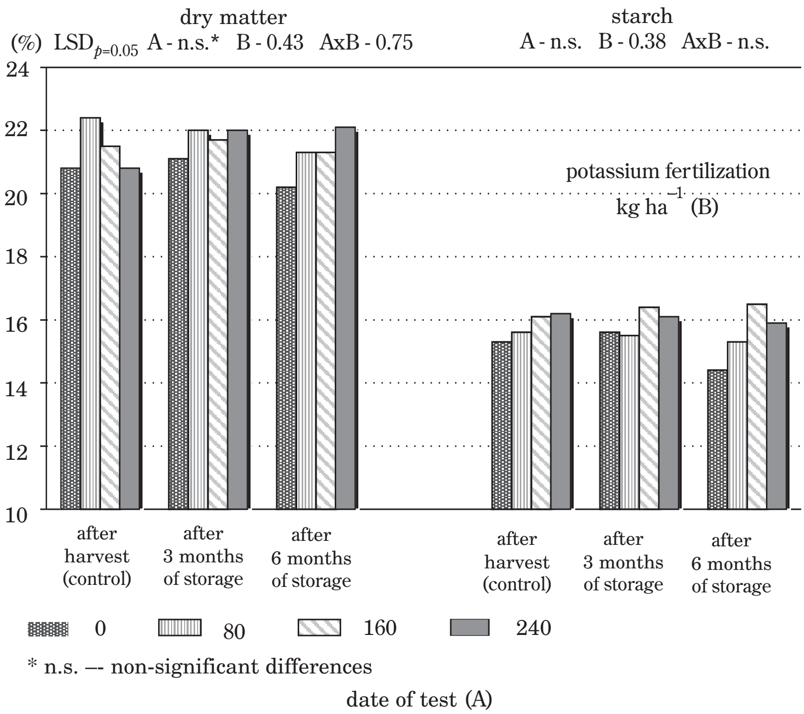

Fig. 2. The dry matter and starch content (%) in cv. Triada potato tubers depending on potassium fertilisation and date of test (means from 3 years)

period after harvest, occurred only after a longer storage (6 months) and it was, respectively, 2.5% for nitrogen experiments and 1.5% for magnesium experiments (mean for years and treatments). Different results were reported by WSZELACZYŃSKA (2002); in the experiment with varied magnesium fertilisation, a decrease in the content of dry matter in tubers was observed after 6 months of storage, as compared to its content after harvest. BOMBIK et al. (2007) report that after 6-month storage there was a significant decrease in the content of dry matter as compared with the control only in the tubers fertilised with higher nitrogen doses, namely (90 kg N ha^{-1}). Interestingly, the research reported by the above authors concerned other potato cultivars than those tested in the present research, that is table potato cultivars Mila and Irga and starch cultivar Ekra.

The most important dry matter component is starch. Its content in potato tubers depends mostly on the genetic factor so it is cultivar specific (GĄSIOROWSKA 2000, ZIMOCH-GUZOWSKA, FLIS 2006), but it is also affected by the storage temperature and time (GĄSIOROWSKA 2000, BOMBIK et al. 2007). The cultivars Bila and Triada, used in the present experiment, differed in the starch content. A higher content of starch was reported in Triada tubers (on average by 3%) – Figures 1, 2, 3. Higher quality tubers can be produced

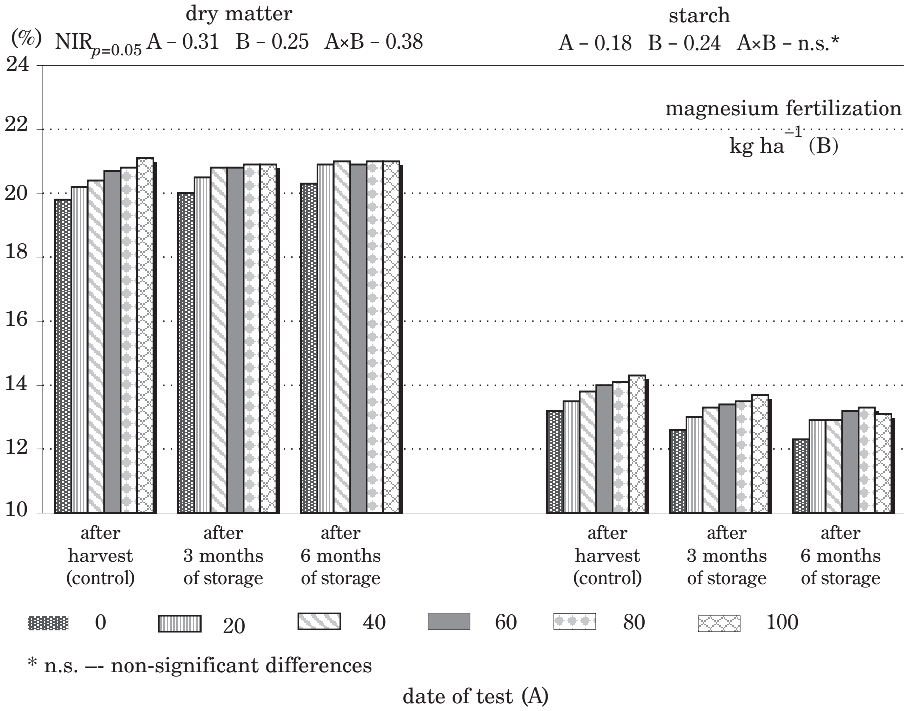

Fig. 3. The dry matter and starch content (%) in cv. Bila potato tubers, depending on magnesium fertilisation and date of test (means from 3 years)

when cultivar-specific differences are taken into account while growing potatoes (BOMBIK et al. 2007). In the present experiment, the content of starch depended on the storage time. After each storage period, the content of starch in tubers decreased, although its significant decrease was noted only for the magnesium treatment, both after 3 and 6 months. BOMBIK et al. (2007) report on a 7-month storage period resulting in a decrease in the content of starch in tubers, which occurred in a nitrogen fertilisation trial. Varied N, K and Mg fertilisation applied over the vegetation period, on the other hand, significantly increased the content of starch in tubers irrespective of the storage period. The doses of 100 kg of nitrogen, 160 kg of potassium and 100 kg of magnesium per hectare, after which the tubers contained 12.9, 16.1 and 14.3% of starch, respectively, turned out to be the most favourable. According to GRUCZEK et al. (2002), potassium fertilisation increases the content of starch if the doses do not exceed 160 to 180 kg K_2O ha^{-1}. The present results, as well as those reported by ROGOZIŃSKA (2000), verify that conclusion. The most favourable increase in the content of starch, as compared with the control, was reported only up to the dose of 160 kg K_2O ha^{-1}, whereas any further increase in the dose, up to 240 kg K_2O ha^{-1}, did not enhance the outcome. DANILCENKO et al. (2006), who fertilised potato with potassium sulphate, also reported an increase in the content of starch. In their experiment, the dose of 90 kg appeared to be the best, with a further increase in potassium fertilisation up to 150 kg causing a slight decrease in the content of starch.

The effect of nitrogen fertilisation on the content of starch in tubers was investigated by BOMBIK et al. (2007), who noticed that its content in tubers decreased as a result of increasing N doses. The relationship persisted after storage. In the present research, on the other hand, an opposite effect was observed: the higher the nitrogen dose, the higher the content of starch. The same relationship was detected after a long period of storage. JABŁOŃSKI (2002) and TRAWCZYŃSKI (2006) found that cultivars representing different earliness groups demonstrated a stable starch level, both when exposed to high and low nitrogen fertilisation. On the other hand, JABŁOŃSKI (2004), who investigated new cultivars of different earliness groups, observed their varied response to nitrogen fertilisation. High nitrogen doses in some cultivars, e.g. Danusia and Wigry, decreased the content of starch significantly, whereas in others, e.g. Wawrzyn and Wolfram, they did not cause any changes.

The interpretation of the results of losses of dry matter and starch in potato tubers after storage obtained from the balance was slightly different as it took into account the real fresh tuber weight losses during storage caused by transpiration and respiration. After each storage period, a decrease in the content of both dry matter and starch was reported, although it is always higher after a longer storage period (6 months) – Tables 1, 2, 3. The highest losses of dry matter and starch after 6 months of storage were observed in the magnesium treatment (8.1 and 15.4%), while lower losses occurred in the nitrogen treatment (6.6 and 10.1%), and the lowest – in the

Table 1

The balance of losses in dry matter and starch after storage in cv. Bila potato tubers, depending on nitrogen fertilisation and date of test (means from 3 years)

Fertilisation N (kg ha^{-1})	Dry matter				Starch			
	date of test							
	after 3 months of storage		after 6 months of storage		after 3 months of storage		after 6 months of storage	
	(%)	(g*)	(%)	(g*)	(%)	(g*)	(%)	(g*)
0	5.8	56.7	7.1	69.3	5.8	34.4	7.6	45.5
50	6.2	61.0	4.9	48.5	8.3	51.4	9.0	56.1
100	7.0	71.0	7.7	77.3	9.9	64.3	13.4	86.5
$\bar{x}$	6.3	62.5	6.6	65.2	8.0	49.7	10.1	62.8

*Actual loss of starch, calculated based on the fresh weight loss during storage of tubers in relation to the weight of the original sample – 10 kg.

Table 2

The balance of losses in dry matter and starch after storage in cv. Triada potato tubers, depending on potassium fertilisation and date of test (means from 3 years)

Fertilisation N (kg ha^{-1})	Dry matter				Starch			
	date of test							
	after 3 months of storage		after 6 months of storage		after 3 months of storage		after 6 months of storage	
	(%)	(g*)	(%)	(g*)	(%)	(g*)	(%)	(g*)
0	4.3	44.7	10.9	113.6	3.8	29.1	13.5	104.2
50	1.9	20.0	6.8	73.8	3.4	26.5	7.2	56.3
160	1.2	12.5	4.8	50.7	0.9	7.5	3.6	29.4
240	2.0	21.2	4.4	47.0	3.3	27.1	7.4	59.9
$\overline{x}$	2.3	24.6	6.7	71.3	2.9	22.6	7.9	62.5

*see Table 1

Table 3

The balance losses in dry matter and starch after storage in cv. Bila potato tubers, depending on magnesium fertilisation and date of test (means from 3 years)

Fertilisation N (kg ha^{-1})	Dry mster				Starch			
	date of test							
	after 3 months of storage		after 6 months of storage		after 3 months of storage		after 6 months of storage	
	(%)	(g*)	(%)	(g*)	(%)	(g*)	(%)	(g*)
0	6.9	68.0	7.5	74.3	11.8	77.6	16.1	106.1
20	3.6	36.3	7.8	78.4	8.7	58.7	14.8	100.3
40	3.1	31.8	7.4	75.7	8.1	56.0	15.7	107.8
60	3.6	37.5	8.5	87.7	8.1	56.2	14.6	101.7
80	4.9	51.2	7.2	74.3	9.6	67.3	13.3	93.8
100	6.2	64.9	10.4	109.4	9.5	68.2	17.6	126.3
$\overline{x}$	4.7	48.4	8.1	83.3	9.3	64.1	15.4	106.0

*see Table 1

potassium treatment (6.7 and 7.9%). The potassium and magnesium doses applied over the vegetation period limited the losses, which could be attributed to the fact that these elements improved the resistance and health of tubers, unlike nitrogen fertilisation (GĄSIOROWSKA 2000). Each nitrogen dose applied increased real losses both of dry matter and starch.

CONCLUSIONS

1. The quality of the tested potato cultivars, for direct consumption or food processing, was improved by the following treatments:
   - dry matter content was better following the application of 100 kg of nitrogen, 80 kg of potassium and 100 kg of magnesium,
   - starch content was higher following the application of 100 kg of nitrogen, 160 kg of potassium as well as 100 kg of magnesium.
2. Real losses of dry matter and starch, as compared with the initial material, were the highest after 6 months of storage, reaching, respectively:
   - 8.1 and 15.4% in the magnesium treatment,
   - 6.6 and 10.1% in the nitrogen treatment,
   - 6.7 and 7.9% in the potassium treatment.

REFERENCES

BOMBIK A., RYMUZA K., MARKOWSKA M., STANKIEWICZ C. 2007. *Variability analysis of selected quantitative characteristics in edible potato varieties*. Acta Sci. Pol., Agric., 6(3); 5-15

CZERKO Z. 2001. *Jak postępować z ziemniakami w przechowalni [How to handle potatoes in a storage room]*. Ziemniak Polski, 4: 20-29. (in Polish)

DANILICENKO H., VENSKUTNONIENE E., BARTASEVICIENE B, PRANAITIENE R. 2006. *Wpływ nawożenia potasowego na jakośc bulw ziemniaka z uprawy ekologicznej*. Cz. 1. *[Effect of potassium fertilisation on quality of potato tubers from organic plantations.* Part 1. *]*. Zesz. Probl. Post. Nauk Rol., 511: 210-215. (in Polish)

EDWARDS C.G., ENGLAR J.W., BROWN C.R., PETERSON J.C., SORENSEN E.J. 2002. *Changes in coulor and sugar content of yellow-fleshed potatoes stored at three different temperatures.* Am. J. Potato Res., 79: 49-56.

GĄSIOROWSKA B. 2000. *Straty przechowalnicze bulw ziemniaka jadalnego i możliwości ich ograniczenia [Storage losses of edible potato tubers and their possible reduction]*. Rozpr., 62: GZ AP Siedlce, 1-170. (in Polish)

GRUCZEK T., LUTOMIRSKA B., SZUTKOWSKA M. 2002. *Różnice w technologii uprawy ziemniaków dla przetwórstwa jadalnych na wczesny zbiór, skrobiowych i sadzeniaków [Differences in the cultivation technologies of processing, early table, starch and seed potatoes].* Red. W. NOWACKIEGO. Wyd. IHAR, Jadwisin, ss. 25-42. (in Polish)

JABŁOŃSKI K. 2002. *Wpływ poziomu nawożenia azotowego nowych odmian ziemniaków jadalnych w latach 1998-2000 na plon i jakość oraz trwałość przechowalniczą [Effect of nitrogen fertilisation level on new table potato cultivars in 1998-2000 on yield, quality and storability].* Zesz. Probl. Post. Nauk Rol., 484: 211-217. (in Polish)

Jabłoński K. 2004. *Wpływ nawożenia azotem nowych odmian ziemniaków skrobiowych [Effect of nitrogen fertilisation on new starch potato cultivars].* Zesz. Probl. Post. Nauk Rol., 500: 253-262. (in Polish)

KREŁOWSKA-KUŁAS M. 1993. *Badanie jakości produktów spożywczych [Tests on quality of foodstuffs]*. PWE, Warszawa. (in Polish)

LISIŃSKA G. 2006. *Wartość technologiczna i jakość konsumpcyjna polskich odmian ziemniaka*. Cz. I. *[Technological value and quality as foodstuff of new Plish potato cultivars*. Part I.*]*. Zesz. Probl. Post. Nauk Rol. 511: 81-94. (in Polish)

LESZCZYŃSKI W. 2000. *Jakość ziemniaka konsumpcyjnego [Quality of tatble potatoes]*. Żywność, Nauka, Technologia, Jakość, 4(25): 5-27. (in Polish)

ROGOZIŃSKA I. 2000. *Znaczenie potasu dla uzyskania wysokiej jakości ziemniaków w Polsce [The role of potassium for obtaining high quality of potatoes in Poland].* Wyd. ATR Bydgoszcz, ss. 1-19. (in Polish)

SOBOL Z. 2005. *Określenie strat ilościowych bulw ziemniaka.* Cz. II. *Ubytki naturalne [Determination of quantitative losses in potato tubers.* Part II. *Natural losses].* Inż. Rol., 10(70): 349-359. (in Polish)

SOWA-NIEDZIAŁKOWSKA G. 2002. *Wpływ naturalnych sposobów ograniczających intensywność przemian ilościowych w bulwach ziemniaka w czasie przechowywania [Effect of natural ways of limiting qualitative changes in potato tubers during storage].* Zesz. Probl. Post. Nauk Rol., 489: 355-363. (in Polish)

SOWA-NIEDZIAŁKOWSKA G. 2004. *Charakterystyka trwałości przechowalniczej odmian ziemniaka w latach 1997-2002 [Specification of the storability of potato cultivars in 1997-2000].* Ziemniak Polski, 3: 7-11. (in Polish)

TRAWCZYŃKI C. 2006. *Ocena skrobiowości nowych odmian ziemniaka pod wpływem nawożenia azotem*. Cz. I. *[Evaluation of the starch content in new potato cultivars under the effect of nitrogen fertilisation*. Part I*].* Zesz. Probl. Post. Nauk Rol., 511: 141-148. (in Polish)

ZGÓRSKA K., SOWA-NIEDZIAŁKOWSKA G. 2005. *Wpływ czynnika termicznego i odmianowego na zmiany jakościowe zachodzące w bulwach ziemniaka w czasie ich długotrwałego przechowywania [Effect of the therman and cultivar – specific factors on qualitative changes in potato tubers during their long-term storage].* Pam. Puł., 139: 327-336. (in Polish)

WSZELACZYŃSKA E. 2002. *Przydatność bulw ziemniaka odmiany Mila nawożonego zróżnicowanymi dawkami magnezu do produkcji wyrobów uszlachetnionych [Suitability of cv. Mila potato fertilised with different rates of magnesium for production of imrpoved foodstuffs].* Acta Sci. Pol. Agric., 1(1): 121-129. (in Polish)

WSZELACZYŃSKA E., JANOWIAK J., SPYCHAJ-FABISIAK E., PIŃSKA M. 2007. *Wpływ nawożenia na wybrane cechy jakościowe bulw ziemniaka odmiany Bila [Effect of fertilisation on some quality attributes of cv. Bila potato tubers].* Acta Sci. Pol. Agric., 6(4): 91-96. (in Polish)

ZIMNOCH-GUZOWSKA E., FLIS B. 2006. *Genetyczne podstawy cech jakościowych ziemniaka [Genetic background of quality traits of potato].* Zesz. Probl. Post. Nauk Rol., 511: 23-36. (in Polish)

ZGÓRSKA K., FRYDECKA-MAZURCZYK A. 1996. *Zmiany cech jakości ziemniaków jadalnych w czasie przechowywania [Changes in qualty attributes of table potatoes during storage].* Ziemniak Polski, 1: 24-27. (in Polish)