The influence of selected cultivation on the content of total protein and amino acids in the potato tubers

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ABSTRACT

The aim of study was to determine the effect of selected cultivation operations, such as nitrogenous fertilization (60, 90 kg N/ha), row spacing (62, 82, 102 cm), compaction of soil with wheels of farm aggregates (the numbers of passing 2×, 5×, 8×), on quality changes of two potato varieties (Irga and Ekra). The total protein content in the tubers of the tested potato varieties increased with the increase of the nitrogenous fertilization (90 kg N/ha). Genotype features of the tested potato tubers define the amino acid limiting the protein biological value (CS) to be leucine in Irga variety and isoleucine in Ekra variety. It is also genotype that influences the second limiting amino acid. It is the sum of sulphuric amino acids (Cys + Met) in respect to Irga variety and valine in respect to Ekra variety. The dose of 90 kg N/ha decreases the protein biological value (EAAI) of the tubers of Ekra variety, which is high in starch.

Keywords: potato; tuber; total protein; biological value of protein; amino acids; nitrogen fertilization; row spacing; soil compaction

Protein content in tubers is an important element of the evaluation of potato quality. Although when compared to other crop plants, potatoes contain a small amount of protein (2.0–2.5% f.m.), they are an important element of human and animal diet, due to high biological value of protein – very good amino acid composition (Ciećko et al. 1999). Potato protein is plant protein of high value for both humans and animals. Potato varieties are characterised by differentiated, genetically conditioned predisposition to protein accumulation in tubers. However, similarly to most quality characteristics, protein content can be modified by various factors, such as environment, soil and tillage (Mazurczyk and Lis 1999). The basic protein components are amino acids, which, similarly to nucleic acids, take part in all intracellular processes in living organisms. The amino acid composition of proteins is important from the nutrition point of view. The amino acid composition determination acids (exogenous), namely tryptophan, phenylalanine, lysine, treonine, methionine, leucine and valine, are valuable. These amino acids are necessary for all types of the examined animals. However, a rigid set of amino acids necessary for all animals cannot be applied because some of them may require specifically a certain type of an amino acid. The analysis of the amino acid composition of the potato protein makes it possible to classify the protein as full-value, as it contains a high amount of the essential amino acids, particularly lysine (Wieczer and Gonczarik 1977).

MATERIAL AND METHODS

The experimental material consisted of the tubers of two varieties: edible Irga and industrial Ekra. A field experiment was carried out in the vegetation seasons of 1997–1999 at the Experimental Farm Station, Zawady and on the experimental field of the Department of Soil Cultivation and Plant Growing, Plant Production Institute of the University of Podlasie in Siedlce. The experiment was planned in the split-bloc-split-plot design with four factors and four replications, on Eutri-Gleyic Albeluvisols (ISSS-ISRIC-FAO 1998). The area of one plot, from which yield was gathered, was 69.3 m^2 whereas the area of the whole experiment was 6171 m^2.

Four factors were analysed in the study variety (O_1 = Irga, O_2 = Ekra), nitrogenous fertilization (N_1 = 60 kg N/ha, N_2 = 90 kg N/ha), row spacing (R_1 = 62 cm, R_2 = 82 cm, R_3 = 102 cm), the density of soil compacted with the wheels of farm aggregates (P_1 = 2 rides, P_2 = 5 rides, P_3 = 8 rides).

Potatoes were planted in the third decade of April, every 20 cm in a row. Rye was used as a forecrop. Phosphorus and potassium fertilization, in the doses of 90 kg P_2O_5 and 140 kg K_2O per 1 ha, was applied in autumn after post-harvest cultivation. Nitrogenous fertilization was applied only once before potato planting, in the form of the urea fertilizer (46%), phosphorus fertilization in the form of the single superphosphate (19%), potassium fertilization as potash salt (60%). Tubers were sampled randomly and in the amount of 3 kg from each plot. Next they were divided into separate varieties. Three samples of each variety were used for analysis, each sample consisting of about 50 tubers of a different size.

Chemical-biochemical analyses were done in three replications on the basis of mixed samples from four field replications.

The total protein content in potato tubers (% d.m.) was calculated by multiplying the total nitrogen content by the protein coefficient 6.25. Total nitrogen was determined by means of Kjeldahl's method (Rutkowska 1981).

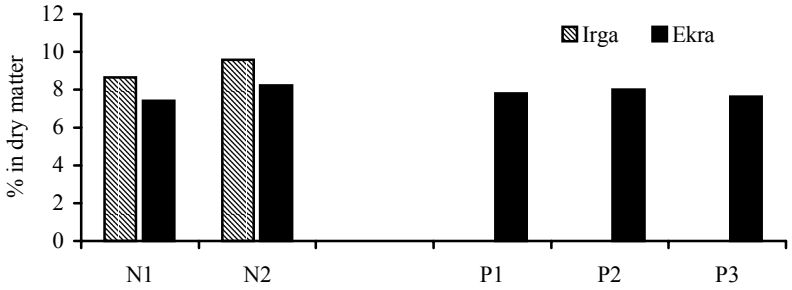

Figure 1. The protein content (N × 6.25) in the tubers of the tested varieties in dependence on nitrogenous fertilization and soil compaction

N_1 = 60 kg N/ha, N_2 = 90 kg N/ha
LSD: Irga = 0.27, Ekra = 0.15
P_1 = 2 rides, P_2 = 5 rides, P_3 = 8 rides
LSD Ekra = 0.23

The amino acid determination was done with the use of an amino acid autoanalyser after HCl acidolysis. The acidolysis was preceded by the addition of cystine to cysteine acid ($CySO_3H$) and the addition of methionine sulfoxide ($MeSO_2$).

The protein biological value was determined by means of indexes: CS – the index of limiting amino acid, calculated with use of Mitchel and Block's method, EAAI – the index of exogenous amino acids calculated with the use of Oser's method.

The estimation of the significance of differences between the experimental factors was done by means of the three-factorial variance analysis, in the completely random design. The value of the least significant difference (*LSD*) was calculated on the basis of Tukey's test at the significance level of $p = 0.05$.

RESULTS AND DISCUSSION

The research showed that the protein content in the tubers of both potato varieties increased significantly under the influence of nitrogenous fertilization (Figure 1). The increased in the total protein content after the application of the higher fertilizer dose (90 kg N/ha) was 10.76% (relative %) for Irga variety and 11.08% (relative %) for Ekra variety. This dependence has been proved by Rogozińska (1995), who concluded that the increase of nitrogen doses regularly increased the total protein content in potato. The high-starch Ekra variety accumulated less protein after the application of the nitrogen doses than the low-starch Irga variety. The higher protein content in the tubers of Irga variety may suggest that genetic factors strongly influence the level of this component. This conclusion remains in accordance with the research of protein Zarzecka (1997). On the contrary, Sikora (1995) has proved that the protein level dose not depends on the group to which a variety belongs (low or high in starch) but on the starch content of a given variety in a given year. In case if the edible Irga variety the interaction of two factors, namely nitrogenous fertilization and the width of inter-rows, was found (Figure 2). The tubers of plants planted in the widest row spacing (102 cm) and fertilized with the dose of 90 kg N/ha contained the greatest amount of total protein. The dose of 60 kg N/ha was the most effective when combined with the smallest row spacing (62 cm). It may be concluded that increasing the width inter-rows should be accompanied by the increase of the dose of nitrogenous fertilization because the portion of it may be used by other plants (weeds) or get washed away from the soil by rainfall. The highest level of this compound (8.01% d.m.) was obtained at the medium soil density (P_2) whereas the lowest (7.63% d.m.) at the highest soil density (P_3). Too low and too high soil compaction negatively influenced the amount of accumulated protein. It can be the result of washing away of nutrients necessary for the growth of plant, which takes place at low soil compaction. The similar interdependence was obtained by Sawicka and Skalski (1993). On the other hand, the highest soil compaction reduces water intake by the root system and hinders the access of the air, which worsen the optimal conditions for the plant development. Such a dependence has been proved by Starczewski et al. (1984), who point to the negative effect of too excessive soil density, on the growth of the root system.

The amino acid composition of potato protein fluctuated and depended, to a high degree, on nitrogenous fertilization and varieties. The protein quality is usually estimated on the basis of necessary amino acids, their sum and reciprocal proportions. Nitrogenous fertilization with the higher dose of 90 kg N/ha decreased the con-

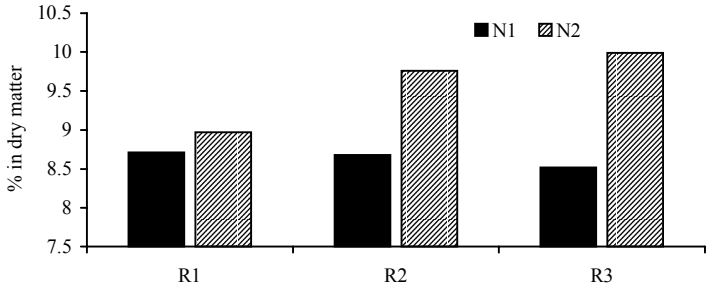

Figure 2. The influence of the interaction (row spacing × nitrogenous fertilization) on protein content (N × 6.25) in the tubers Irga variety

R_1 = 62 cm, R_2 = 82 cm, R_3 = 102 cm
N_1 = 60 kg N/ha, N_2 = 90 kg N/ha
LSD = 0.47

Table 1. The influence of nitrogenous fertilization on the content of exogenous amino acids (g/100 g of protein); means for seasons 1998–1999

Exogenous amino acids	Irga		Ekra	
	60 kg N/ha	90 kg N/ha	60 kg N/ha	90 kg N/ha
Liz	4.22	4.04	4.18	3.99
Thr	2.70	2.99	3.23	3.08
Cys	0.63	0.87	0.89	0.78
Wal	3.20	4.13	3.61	3.07
Met	1.27	1.71	2.03	1.88
Ileu	3.12	2.77	2.66	2.27
Leu	3.48	2.79	5.28	4.15
Tyr	3.20	2.79	3.27	3.49
Phe	6.09	5.13	4.22	3.05
Σ	27.93	26.89	29.85	25.78
$LSD_{0.05}$	n.s.		n.s.	

Table 2. The average value of the protein index CS and EAAI of the tubers of the tested potato varieties

Index	Aminoacids	Variety	
		Irga (%)	Ekra (%)
CS	Liz	59.03	73.82
	Thr	60.51	67.23
	Cys + Met	39.33**	49.07
	Val	59.53	46.36**
	Ileu	54.63	44.77*
	Leu	36.51*	51.80
	Tyr + Phe	95.78	72.93
EAAI		54.49	54.74

* the first limited amino acid, ** the second limited amino acid
CS – chemical score, EAAI – index essential amino acids

tent of the sum of exogenous amino acids in protein of both tested potato varieties (Table 1). However, the obtained results did not differ significantly.

The content exogenous amino acids in tubers of Irga and Ekra potato varieties determined the nutritive value of tuber protein (Figure 3). The average protein nutritive value of the edible variety cultivated at the dose of 60 kg N/ha was 53.76% (EAAI), and of the industrial variety 58.05%. The significant decrease of protein biological value by about 11% (relative value) resulted from the application of the higher dose (90 kg N/ha) of nitrogenous fertilization only in case of the industrial variety. In the discussed experiment the higher dose of nitrogenous fertilization (90 kg N/ha) increased the total protein content in the tubers of Ekra variety but decreased the protein biological value. The dependence has been confirmed by the study Schuphan (1959), who found that the increase of the total protein content in tubers decreases its biological value. The positive influence of increasing doses of nitrogenous fertilisation on the protein biological value has been mentioned by Wojtas and Szagała (1991). The protein biological value of the edible variety increased by 3% but the obtained difference was not significant.

Leucine – 36.51% is the first amino acid limiting the protein nutritive value of Irga variety and isoleucine – 46.36% of Ekra variety. Sulphuric amino acids are the second limiting amino acid in edible variety (Cys + Met – 39.33%) and valine is the second limiting amino acid in the industrial variety – 46.36% (Table 2). Rotkiewicz et al. (1994) included tryptophan to the group of exogenous amino acids. He additionally concluded that it is tryptophan that limits the protein nutritive value in the tubers of Irga variety, which remains in the opposition to the results of the discussed experiment.

As far as the industrial variety is concerned, the dose of 90 kg N/ha decreased the protein biological value with the simultaneous decrease in the sum of exogenous amino acids in protein. Similar results have been obtained by Ciećko et al. (1999), who proved that the effect of nitrogenous fertilisation on the protein nutritive of potato tubers was similar in respect to the sum of the determined exogenous amino acids.

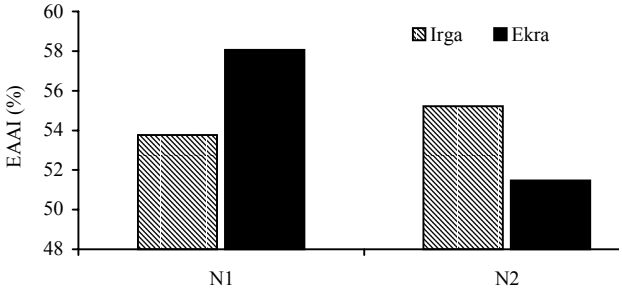

Figure 3. Protein biological value (EAAI) in the tested potato tubers in dependence on nitrogenous fertilization.

N_1 = 60 kg N/ha, N_2 = 90 kg N/ha
LSD: Irga = n.i., Ekra = 5.91

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ABSTRAKT

Vliv vybraných agrotechnických opatření na obsah proteinů a aminokyselin v hlízách brambor

Byl sledován vliv vybraných agrotechnických opatření (hnojení dusíkem 60 a 90 kg N/ha), meziřádkové vzdálenosti (62, 82 a 102 cm) a utužení půdy koly souprav strojů (počet přejezdů 2×, 5× a 8×) na změny kvality u dvou odrůd brambor (Irga a Ekra). Celkový obsah proteinů v hlízách pokusných odrůd brambor se zvyšoval s vyšší dávkou dusíkatého hnojení (90 kg N/ha). Genotypové znaky hlíz brambor předurčují aminokyselinu kritickou pro biologickou hodnotu proteinů (CS): leucin u odrůdy Irga a izoleucin u odrůdy Ekra. Genotyp rovněž ovlivňuje druhou kritickou skupinu aminokyselin. Jde o aminokyseliny s obsahem síry (Cys + Met) u odrůdy Irga a o valin u odrůdy Ekra. Dávka 90 kg N/ha snižuje biologickou hodnotu proteinů (EAAI) u hlíz odrůdy Ekra, která se vyznačuje vysokým obsahem škrobu.

Klíčová slova: brambor; hlíza; proteiny; biologická hodnota proteinů; aminokyseliny; dusíkaté hnojení; meziřádková vzdálenost; utužení půdy

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