

# The effect of selected factors on the content of protein and nitrates in potato tubers

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## ABSTRACT

The aim of the study was to determine the effect of region, variety, year and ecological and conventional way of cultivation on the content of total protein and nitrates in potato tubers in three-year field trials. The effects of selected factors on nitrate and protein contents were similar, more significant for nitrates. Growing regions, varieties and years of cultivation caused statistically significant effects whereas the effect of ecological way of cultivation was less pronounced and showed a tendency without significance. Higher region showed lesser average nitrate (113.4 mg/kg) and protein content (4.27% dry matter) in comparison with lower region (143.7 mg/kg and 4.72% dry matter). The highest nitrate content was found in Impala and Karin varieties (199.2 and 167.6 mg/kg); Karin variety was also rich in total proteins (4.86% dry matter). Ecological way of cultivation showed no significant difference on nitrate content (136.9 mg/kg) and protein content (4.41%) as compared with conventional way of cultivation (153.9 mg/kg, 4.32%).

**Keywords:** potato; tuber; total protein; nitrates; growing regions; variety; year; conventional cultivation; ecological cultivation

Nitrogen contained in potato tubers can be present either in the form of proteins and amino acids or nitrates/glycoalkaloids. These forms are very important with respect to possible impacts on human health. Protein content in tubers is an important positive element of the evaluation of potato quality (Mitrus et al. 2003). Recent estimates of protein content in potatoes were 16–25 g/kg of fresh matter (Harris 1992). Though potatoes are not usually regarded as a protein source because of their low protein content, they are an important constituent of alimentation in European countries and can make a significant nutritional contribution. Duke (1992a, b) states the protein content in potato tubers as 10–127 g/kg and total nitrogen 2.2–17 g/kg. The skin contains more proteins (26 g/kg) in comparison with the whole tuber (21 g/kg). The protein content can vary for different cultivars and between crops of the same variety depending on location, fertiliser usage and crop maturity (Mitrus et al. 2003, Long et al. 2004, Zebarth et al. 2004). Some authors report on using of low-glycoalkaloid potato protein as the main protein source for the nutrition of weaner piglets (Pedersen and Lindberg 2004). Conditions of cultivation, harvesting, handling in the packinghouse

and storage are the main factors affecting the quality of potatoes (Galido et al. 2004).

The way of cultivation, esp. nitrogen nutrition can affect also the pathway of nitrate transport into tubers (Lin et al. 2004). Nitrogen and especially nitrate form accumulations are highly affected by potato cultivars (Hamouz et al. 1999a, b, Alva et al. 2002), but also by other conditions of the cultivation, such as irrigation (Belanger et al. 2002) and the way of cultivation (Lindhauer and Weber 1993), and an introduction of transgenic potato cultivars with a modified nitrate reductase expressions (Djennane et al. 2002a, b). Conventional and organic potatoes attract more and more attention regarding their assessment of element composition (Bacchi et al. 2004) or tubers quality (Hamouz et al. 1999a, b), and so there is the need of more knowledge about their constituents affecting positively or negatively their quality.

## MATERIAL AND METHODS

**Material.** In the years 1995–1997 in the field trials on twelve localities in the Czech Republic potato varieties Impala, Karin, Korela, Rosella,

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Santé and Ornella were cultivated under unified conditions of planting. Six localities were situated in a lower, warmer and drier region with fertile, predominantly loam soils (prevail Orthic Luvisol and black Luvic Chernozem) and in this study they are indicated by common term "lower region" (in Czech Republic mainly beet-growing region). Lower region is characterised by average altitude of 244 m above sea level, average temperature 15.2°C and average precipitation 360.1 mm in vegetation period April–September. Other six localities were situated in a higher, cooler and more humid region with less fertile, predominantly sandy loam soils (prevails Cambisol) and it represents a traditional potato growing region in the Czech Republic. In our study we indicate them as "higher region". It is characterised by average values of altitude 531 m, temperature 12.7°C and sum of precipitation 424.7 mm in vegetation period April–September. Besides, trials in two of the localities included another variant – the ecological way of cultivation without using chemical protection and industrial fertilisers.

**Determination of nitrates.** For nitrate content tubers were analysed with ion selective electrode

– ISE (Nitrate XQ-1 Orion, Boston) (Davídek et al. 1977).

**Determination of proteins.** Proteins were determined by precipitation with copper reagent as described by Barstein. 1–2 g of homogenized sample were mixed with 50–100 ml of distilled water in a beaker and boiled for 2 min. 25 ml of CuSO<sub>4</sub> solution was added with pipette and under permanent agitation 25 ml of NaOH solution was added in drops from the burette. After sedimentation the sediment was decanted and then washed on the filter by hot distilled water until the filtrate gave a positive reaction for Cu (II) cation with potassium ferrocyanide. Nitrogen was determined by Kjeldahl method in the precipitation on the filter. Analyses were performed at the Faculty of Agronomy of CUA in Prague.

**Statistic evaluation.** For the statistical evaluation of obtained results SAS 6.12 was used.

## RESULTS AND DISCUSSION

**Nitrates.** Results of the determination of nitrates are given in Tables 1–3, the statistical evaluation

Table 1. Nitrate content in 1995 (mg/kg)

Locality	Varieties							Average of varieties
	Impala	Karin	Agria	Korela	Rosella	Santé	Ornella	
Suchdol	199	201	74	177	195	150	125	160.3
Uherský Ostroh	300	318	160	180	244	200	147	221.4
Ivanovice na Hané	261	360	115	225	197	157	139	207.8
Čáslav	257	157	81	120	144	136	118	144.6
Přerov nad Labem	132	198	64	166	185	223	110	154.0
Uhříněves	462	299	193	305	231	222	183	270.8
Average of lower region	268.5	255.7	114.5	195.5	199.2	181.5	137.1	193.2
Domanínec	n.d.	131	98	135	163	195	125	141.3
Hradec nad Svitavou	190	208	99	185	203	149	146	168.5
Chrastava	n.d.	190	95	144	233	162	n.d.	164.8
Lípa	225	280	87	158	109	96	96	150.0
Stachy	150	115	73	71	67	67	66	86.8
Valečov	223	203	71	134	151	93	n.d.	145.9
Average of higher region	199.1	187.6	87.3	137.7	154.5	126.9	122.3	145.1
Average of twelve localities	245.4	221.6	95.0	166.6	177.2	154.2	124.9	169.3
Uhříněves conventional cultivation	462	299	193	305	231	222	n.d.	285.4
Uhříněves ecological cultivation	252	286	173	210	219	198	n.d.	223.0
Valečov conventional cultivation	223	203	71	134	151	93	n.d.	145.9
Valečov ecological cultivation	233	178	67	158	113	108	n.d.	142.8
Aver. Uhříněves, Valečov conventional cult.	342.8	250.9	132.0	219.5	191.1	157.6	n.d.	215.7
Aver. Uhříněves, Valečov ecological cult.	242.5	231.9	120.0	183.8	165.9	153.2	n.d.	182.9

n.d. = not determined

Table 2. Nitrate content in 1996 (mg/kg)

Locality	Varieties							Average of varieties
	Impala	Karin	Agria	Korela	Rosella	Santé	Ornella	
Suchdol	137	122	47	65	92	61	61	83.6
Uherský Ostroh	269	233	88	168	120	200	157	176.4
Ivanovice na Hané	191	124	42	150	94	76	64	106.0
Čáslav	175	104	46	108	74	72	74	93.3
Přerov nad Labem	206	212	104	98	128	80	125	136.1
Uhříněves	215	106	57	85	64	88	61	96.6
Average of lower region	199.0	150.0	63.9	112.3	95.6	96.2	90.2	115.3
Domanínek	43	185	41	119	37	34	54	73.1
Hradec nad Svitavou	226	214	49	90	48	73	42	106.1
Chrastava	90	88	49	74	54	75	71	71.4
Lípa	220	107	55	123	87	188	71	121.6
Stachy	151	98	61	103	87	129	77	100.7
Valečov	164	176	48	135	88	85	103	114.0
Average of higher region	149.0	144.5	50.5	107.1	66.7	97.3	69.5	97.8
Average of twelve localities	174.0	147.3	57.2	109.7	81.1	96.7	79.9	106.6
Uhříněves conventional cultivation	215	106	57	85	64	88	61	96.6
Uhříněves ecological cultivation	84	149	61	104	87	96	84	94.7
Valečov conventional cultivation	164	176	48	135	88	85	103	114.0
Valečov ecological cultivation	184	156	46	118	62	64	85	102.2
Aver. Uhříněves, Valečov conventional cult.	189.6	141.1	52.5	109.8	75.9	86.4	81.7	105.3
Aver. Uhříněves, Valečov ecological cult.	133.8	152.4	53.2	110.9	74.4	79.9	84.6	98.5

Table 3. Nitrate content in 1997 (mg/kg)

Locality	Varieties							Average of varieties
	Impala	Karin	Agria	Korela	Rosella	Santé	Ornella	
Suchdol	268	256	48	195	124	108	104	157.7
Uherský Ostroh	225	123	65	123	163	133	94	132.4
Ivanovice na Hané	191	123	50	128	120	80	80	110.2
Čáslav	212	86	49	95	142	153	82	116.9
Přerov nad Labem	146	77	78	80	79	99	61	88.5
Uhříněves	271	165	69	118	95	116	80	130.5
Average of lower region	218.8	138.2	59.8	123.3	120.5	114.9	83.4	122.7
Domanínek	18	115	70	85	66	63	56	67.5
Hradec nad Svitavou	135	118	55	73	77	63	76	85.3
Chrastava	159	120	67	87	82	81	60	93.8
Lípa	170	137	52	99	125	84	71	105.6
Stachy	95	81	47	133	67	61	69	79.1
Valečov	248	206	50	162	121	163	112	151.8
Average of higher region	137.5	129.6	57.0	106.6	89.8	85.6	74.2	97.2
Average of twelve localities	178.1	133.9	58.4	114.9	105.2	100.2	78.8	109.9
Uhříněves conventional cultivation	271	165	69	118	95	116	80	130.5
Uhříněves ecological cultivation	206	115	43	93	142	76	77	107.2
Valečov conventional cultivation	248	206	50	162	121	163	112	151.8
Valečov ecological cultivation	244	176	57	206	115	168	101	152.4
Aver. Uhříněves, Valečov conventional cult.	259.3	185.6	59.8	140.0	108.0	139.3	95.9	141.1
Aver. Uhříněves, Valečov ecological cult.	225.0	145.2	50.0	149.5	128.4	122.2	88.6	129.8

Table 4. Nitrate content affected by region, variety, year and way of cultivation (mg/kg)

	1995		1996		1997		1995–1997	
	average	sign.	average	sign.	average	sign.	average	sign.
<b>Influence of region on nitrate content</b>								
Lower region	193.2	A	115.3	A	122.7	A	143.7	A
Higher region	145.1	B	97.8	A	97.2	B	113.4	B
Difference between regions	48.1		17.5		25.5		30.3	
<i>LSD</i>	25.16		18.32		15.78		11.37	
<b>Influence of variety on nitrate content</b>								
Impala	245.4		174.0		178.1		199.2	A
Agria	95.0		57.2		58.4		70.2	D
Karin	221.6		147.3		133.9		167.6	A
Santé	154.2		96.7		100.2		117.0	BC
Rosella	177.2		81.1		105.2		121.2	BC
Korela	166.6		109.7		114.9		130.4	B
Ornella	124.9		79.9		78.8		94.5	CD
<i>LSD</i>	63.59		67.92		69.78		38.15	
<b>Influence of the year of cultivation on nitrate content</b>								
		average			significance			
1995		168.9			A			
1996		107.0			B			
1997		112.4			B			
<i>LSD</i>		16.67						
<b>Influence of the way of cultivation on nitrate content</b>								
Conventional (C)	215.2	A	105.3	A	141.1	A	153.9	A
Ecological (E)	182.5	A	98.5	A	129.8	A	136.9	A
Difference between C and E	32.7		6.8		11.3		17.0	
<i>LSD</i>	37.65		27.30		29.43		27.37	

of the effects of selected factors in Table 4. In consumers discussions concerning table potato quality nitrate content and the aim to lower it is still a highly important issue with respect to possible negative impacts on human health (Meinolf et al. 1993). During the experiment nitrate content was highly (statistically significantly) affected by regions, varieties and significant differences were found between years 1995 and 1996, 1997. Higher region showed lesser average nitrate content (113.4 mg/kg) in comparison with lower region (143.7 mg/kg). Significant differences were found between varieties: Impala × Agria, Santé, Rosella, Korela, Ornella; Agria × Impala, Karin, Santé, Rosella, Korela; Karin × Agria, Santé, Rosella,

Korela, Ornella; Santé and Rosella × Impala, Agria, Karin; Korela × Impala, Agria, Karin, Ornella; and Ornella × Impala, Karin and Korela. The highest average nitrate contents were found in Impala and Karin varieties (199.2 and 167.6 mg/kg respectively) and the lowest contents in Agria and Ornella varieties (70.2 and 94.5 mg/kg respectively.). Contrary to the effect of regions, varieties and years of cultivation, no significant differences were found between ecological and conventional ways of cultivation for nitrate content. But the tendency could be observed to higher nitrate content by conventional way of cultivation (153.9 mg/kg) as compared with ecological way of cultivation (136.9 mg/kg) caused by higher nitrogenous fertilization.

Table 5. Protein content in 1995 (% dry matter)

Locality	Varieties					Average of varieties
	Karin	Agria	Korela	Rosella	Santé	
Suchdol	5.77	5.77	5.42	5.34	5.07	5.47
Uherský Ostroh	5.36	5.18	4.11	5.77	5.82	5.25
Ivanovice na Hané	5.87	5.88	5.54	4.91	5.58	5.56
Čáslav	4.90	5.42	4.17	4.80	4.16	4.69
Přerov nad Labem	4.23	3.36	3.97	4.15	4.90	4.12
Uhříněves	4.21	4.82	4.75	5.41	5.16	4.87
Average of lower region	5.05	5.07	4.66	5.06	5.12	4.99
Domanínek	4.02	3.76	4.14	4.11	4.51	4.11
Hradec nad Svitavou	5.31	4.19	4.47	3.98	4.93	4.58
Chrastava	4.65	3.99	3.68	3.55	3.66	3.91
Lípa	5.44	3.38	4.37	4.52	4.83	4.51
Stachy	4.97	3.98	4.07	4.64	3.44	4.22
Valečov	4.48	5.51	3.58	4.80	4.01	4.48
Average of higher region	4.81	4.13	4.05	4.27	4.23	4.30
Average of twelve localities	4.93	4.60	4.36	4.66	4.67	4.65
Uhříněves conventional cultivation	4.21	4.82	4.75	5.41	5.16	4.87
Uhříněves ecological cultivation	5.14	5.20	4.50	5.75	4.85	5.09
Valečov conventional cultivation	4.48	5.51	3.58	4.80	4.01	4.48
Valečov ecological cultivation	5.23	4.21	4.57	4.45	4.63	4.62
Average Uhříněves, Valečov conventional cultivation	4.37	5.15	4.16	5.10	4.58	4.67
Average Uhříněves, Valečov ecological cultivation	5.20	4.73	4.52	5.10	4.73	4.85

Table 6. Protein content in 1996 (% dry matter)

Locality	Varieties					Average of varieties
	Karin	Agria	Korela	Rosella	Santé	
Suchdol	4.99	5.17	4.04	3.99	4.08	4.45
Uherský Ostroh	5.86	5.15	5.26	5.25	5.32	5.37
Ivanovice na Hané	5.36	3.98	4.51	4.56	4.62	4.61
Čáslav	3.45	3.69	3.23	3.18	3.30	3.37
Přerov nad Labem	5.37	4.71	3.95	3.52	4.23	4.35
Uhříněves	4.61	3.33	3.93	3.21	3.77	3.77
Average of lower region	4.94	4.34	4.15	3.95	4.22	4.32
Domanínek	6.05	3.97	4.99	4.45	4.97	4.89
Hradec nad Svitavou	4.35	4.89	4.13	3.75	4.66	4.36
Chrastava	4.51	3.29	3.22	3.39	3.23	3.53
Lípa	4.63	4.16	4.44	4.20	4.71	4.43
Stachy	4.47	4.31	4.32	3.65	3.81	4.11
Valečov	4.91	3.93	4.06	3.75	3.91	4.11
Average of higher region	4.82	4.09	4.19	3.87	4.22	4.24
Average of twelve localities	4.88	4.22	4.18	3.91	4.22	4.28
Uhříněves conventional cultivation	4.61	3.33	3.93	3.21	3.77	3.77
Uhříněves ecological cultivation	3.68	3.14	3.12	3.56	3.17	3.33
Valečov conventional cultivation	4.91	3.93	4.06	3.75	3.91	4.11
Valečov ecological cultivation	4.53	4.28	3.45	3.53	3.71	3.90
Average Uhříněves, Valečov conventional cultivation	4.76	3.63	3.99	3.48	3.84	3.94
Average Uhříněves, Valečov ecological cultivation	4.10	3.71	3.29	3.55	3.44	3.62

Table 7. Protein content in 1997 (% dry matter)

Locality	Varieties					Average of varieties
	Karin	Agria	Korela	Rosella	Santé	
Suchdol	4.92	6.01	5.17	6.00	5.31	5.48
Uherský Ostroh	5.69	5.01	3.69	5.25	5.53	5.03
Ivanovice na Hané	5.96	6.67	4.39	4.36	5.28	5.33
Čáslav	3.78	5.51	5.50	3.59	4.69	4.61
Přerov nad Labem	4.05	4.04	3.70	4.58	5.25	4.32
Uhříněves	4.63	3.79	3.99	4.63	4.39	4.28
Average of lower region	4.84	5.17	4.41	4.73	5.08	4.84
Domanínec	4.48	3.94	3.82	3.75	4.28	4.06
Hradec nad Svitavou	4.74	4.60	4.36	3.63	4.27	4.32
Chrastava	4.88	4.59	4.30	4.31	4.72	4.56
Lípa	5.63	4.47	4.47	4.52	4.79	4.78
Stachy	3.84	3.81	3.58	2.99	3.71	3.58
Valečov	4.77	4.00	4.34	4.30	4.69	4.42
Average of higher region	4.72	4.23	4.15	3.92	4.41	4.29
Average of twelve localities	4.78	4.70	4.28	4.33	4.74	4.56
Uhříněves conventional cultivation	4.63	3.79	3.99	4.63	4.39	4.28
Uhříněves ecological cultivation	4.57	4.79	4.54	4.92	4.41	4.65
Valečov conventional cultivation	4.77	4.00	4.34	4.30	4.69	4.42
Valečov ecological cultivation	5.34	4.30	4.78	5.07	4.86	4.87
Average Uhříněves, Valečov conventional cultivation	4.70	3.89	4.17	4.46	4.54	4.35
Average Uhříněves, Valečov ecological cultivation	4.95	4.55	4.66	5.00	4.64	4.76

**Proteins.** Results of the determination of protein contents are given in Tables 5–7 (varieties Karin, Korela, Rosella, Santé) and the statistical evaluation of selected factors on protein content in Table 8. Potatoes are a significant source of proteins for their high per capita consumption; the estimation of total protein intake is 3.4% (Harris 1992). The high quality dietary nitrogen in potatoes means that 100 g of boiled potato supplies 8–13% of the FAO-WHO recommended daily allowance (RDA) of protein for children and 6–7% of the adult RDA. Analogical differences as in the case of nitrates were found also for protein content. Significant differences were found between regions in the years 1995, 1997 and 1995–1997 average; similarly significant differences were found between varieties in 1996 and 1995–1997 average, esp. for Karin × Rosella, Korela (4.86 vs. 4.27 and 4.30% dry matter, respectively). Genotype features of the tested potato tubers are substantial for the nutritive value and content of potato protein (Mitrus et al. 2003). Lower region showed significantly higher average protein content in comparison with higher region (4.72% dry matter vs. 4.27% dry matter). Considerable differences were found between years 1995, 1997 × 1996 (4.65% dry matter in 1995, 4.28% dry matter in 1996). Ecological way of cultivation showed no important

effect on protein content – the differences were not significant as the content in ecologically cultivated potatoes was only a little higher.

It can be seen from obtained results that variety, growing area and year of cultivation have an important role in nitrate and protein contents whereas the influence of the way of cultivation is lesser.

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Table 8. Protein content affected by region, variety, year and way of cultivation (% dry matter)

	1995		1996		1997		1995–1997	
	average	sign.	average	sign.	average	sign.	average	sign.
<b>Influence of region on protein content</b>								
Lower region	4.99	A	4.32	A	4.84	A	4.72	A
Higher region	4.30	B	4.24	A	4.28	B	4.27	B
Difference between regions	0.69		0.08		0.56		0.45	
<i>LSD</i>	0.33		0.35		0.35		0.19	
<b>Influence of variety on protein content</b>								
Agria	4.60	A	4.22	AB	4.70	A	4.51	AB
Karin	4.93	A	4.88	A	4.78	A	4.86	A
Santé	4.67	A	4.22	AB	4.74	A	4.54	AB
Rosella	4.66	A	3.91	B	4.32	A	4.30	B
Korela	4.36	A	4.18	AB	4.28	A	4.27	B
<i>LSD</i>	0.73		0.77		0.78		0.42	
<b>Influence of the year of cultivation on protein content</b>								
	average				significance			
1995	4.65				A			
1996	4.28				B			
1997	4.57				A			
<i>LSD</i>	0.28							
<b>Influence of the way of cultivation on protein content</b>								
Conventional (C)	4.67	A	3.94	A	4.35	A	4.32	A
Ecological (E)	4.85	A	3.62	A	4.76	B	4.41	A
Difference between C and E	0.18		0.32		0.39		0.09	
<i>LSD</i>	0.55		0.39		0.27		0.22	

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## ABSTRAKT

### Vliv vybraných faktorů na obsah bílkovin a dusičnanů v hlízách brambor

Cílem práce bylo stanovit vliv oblasti, odrůdy, roku a ekologického a konvenčního způsobu pěstování na obsah celkových bílkovin a dusičnanů v bramborových hlízách v tříletých polních pokusech. Vlivy vybraných faktorů byly podobné, významnější byly u dusičnanů. Pěstební oblasti, odrůdy a roky pěstování prokázaly statisticky významný vliv na obsah celkových bílkovin a dusičnanů, zatímco vliv ekologického způsobu pěstování byl méně významný a projevil se pouze jako trend. Výše položená oblast vykazovala nižší průměrný obsah dusičnanů (113,4 mg/kg) a celkových bílkovin (4,27 % sušiny) ve srovnání s níže položenou oblastí (143,7 mg/kg a 4,72 % sušiny). Nejvyšší obsah dusičnanů byl nalezen u odrůd Impala a Karin (199,2 a 167,6 mg/kg), odrůda Karin měla také nejvyšší obsah celkových bílkovin (4,86 % sušiny). Ekologický způsob pěstování neprokázal významný rozdíl v obsahu dusičnanů (136,9 mg/kg) ve srovnání s konvenčním způsobem pěstování (153,9 mg/kg) a rovněž v obsahu celkových bílkovin (4,41 a 4,32 %).

**Klíčová slova:** brambor; hlíza; celkové bílkoviny; dusičnany; pěstební regiony; odrůda; ročník; konvenční pěstování; ekologické pěstování

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