CRUDE PROTEIN CONTENT IN TUBERS OF STARCH PROCESSING POTATO CULTIVARS IN DEPENDENCE ON DIFFERENT AGRO-ECOLOGICAL CONDITIONS
VLIV AGROEKOLOGICKÝCH PODMÍNEK NA OBSAH HRUBÉHO PROTEINU V HLÍZÁCH PRŮMYSLOVÝCH ODRŮD BRAMBOR

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ABSTRACT

Crude protein content in dry matter of processing potato tubers cultivated in the Czech Republic in 2004-2005 on three sites with different altitudes and two variants of N fertilization ranged from 5.86 to 11.16%. Differences in crude protein content between doses of 100 kg N ha^{-1} and 200 kg N ha^{-1} were significant ($P<0.05$), resulted at average in 7.5 and 8.4% of dry matter of potato tubers, respectively. The variability of crude protein content was above all affected by cultivar (34.3%). The yield of crude protein per area unit ranged from 426 to 1279 kg ha^{-1} and was affected mainly by the year (24.1%) and by interaction of the year and the site (41.5%). The increasing altitude caused at average increasing of tuber yield and consequently increasing of crude protein yield per area unit. However, crude protein content showed opposite trend and the lowest concentration (7.5%) was achieved on the site with the highest altitude.

Key words: Processing potato cultivars; Potato tubers protein; Nitrogen fertilization; Agro-ecological conditions; Potato crude protein yield

ABSTRAKT

Studie se zabývá obsahem hrubého proteinu v sušině hlíz průmyslových odrůd brambor, které byly napěstovány v letech 2004 až 2005 v České republice na třech stanovištích s odlišnou nadmořskou výškou v kombinaci s využitím dvou dávek dusíkatého hnojení. Obsah hrubého proteinu v sušině hlíz průmyslových brambor se pohyboval v rozmezí 5.86 až 11.16%. Navýšení dávky dusíku ze 100 kg N ha^{-1} na 200 kg N ha^{-1} průkazně ($P<0.05$) zvýšilo obsah hrubého proteinu v sušině hlíz brambor. V průběhu studie byla zjištěna významná odrůdová variabilita obsahu hrubého proteinu. Výnos hrubého proteinu z jednotky plochy se pohyboval v rozmezí 426 až 1279 kg ha^{-1} a byl ovlivněn především ročníkem (24.1%) a kombinací ročníku a stanoviště (41.5%). Na stanovištích s vyšší nadmořskou výškou byl zaznamenán nárůst produkce hrubého proteinu na jednotku plochy, ovšem obsah hrubého proteinu v sušině hlíz byl na stanovišti s nejvyšší nadmořskou výškou nejnižší (7.5%)

Klíčová slova: průmyslové odrůdy brambor, hrubý protein hlíz brambor, dusíkaté hnojení, agroekologické podmínky, výtěžnost hrubého proteinu hlíz brambor

DETAILNÍ ABSTRAKT

Studie se zabývá obsahem hrubého proteinu v sušině hlíz průmyslových odrůd brambor a jeho výnosem z jednotky plochy. Vliv agroekologických faktorů na obsah hlízového proteinu je popsán především u konzumních brambor. Obdobné studie u průmyslových odrůd v podstatě neexistují, přestože znalost vlivu agroekologických faktorů na obsah a výnos hrubého proteinu u těchto odrůd je podmínkou pro zamýšlenou izolaci proteinu z hlízové vody, jenž vzniká jako vedlejší produkt při zpracování brambor na škrob. Analyzované hlízy byly získány v polním pokusu vedeném v České republice v letech 2004 až 2005 na stanovištích s odlišnou nadmořskou výškou - České Budějovice (381 m), Volyně (460 m) a Lukavec (610 m). V pokusu bylo použito sedm průmyslových odrůd (Tomensa, Rebel, Westamyl, Ornella, Amylon, Kuras, Sibu) a dvě varianty dusíkatého hnojení (100 kg N ha^{-1}; 200 kg N ha^{-1}). Obsah hrubého proteinu v sušině hlíz se v rámci uvedených variant pohyboval od 5.86% (Amylon, České Budějovice, 2005, 100N) do 11.16% (Ornella, České Budějovice, 2004, 200N). Obsah hrubého proteinu v sušině hlíz byl dán především odrůdou, jenž se na celkové variabilitě obsahu podílela ze 34%. Nejvyšší průměrná koncentrace hrubého proteinu byla zaznamenána u odrůdy Tomensa (8.95%). Navýšení dávky dusíku ze 100 kg N ha^{-1} na 200 kg N ha^{-1} průkazně ($P<0.05$) zvýšilo obsah hrubého proteinu v hlízách brambor. Výtěžnost hrubého proteinu z jednotky plochy se pohybovala u sledovaných variant od 426 kg ha^{-1} do 1279 kg.ha^{-1}. Tento ukazatel je dán především produkcí hlíz ($r = 0.75$, $P < 0.01$) a z tohoto důvodu je významný vliv interakcí mezi ročníkem a stanovištěm (41.6%). Vliv dusíkatého hnojení a odrůdy byl vyhodnocen jako neprůkazný. Z hlediska produkce hrubého proteinu byly optimální klimatické podmínky v roce 2005 (v průměru 978.7 kg ha^{-1}). Nejvyšších výnosů bylo dosaženo na stanovišti Lukavec (průměrný výnos 994.8 kg ha^{-1}). Rozdíly mezi odrůdami nebyly ve výnosu hrubého proteinu statisticky průkazné, ovšem pro praxi lze doporučit odrůdu Kuras s průměrným výnosem hrubého proteinu 915 kg ha^{-1}.

INTRODUCTION

Potato (Solanum tuberosum L.) cultivars used in starch industry are primarily grown for high dry matter and starch yields [9]. The Czech Republic has assigned the starch quota in amount of 33 660 t of starch which means annually production of 259 000 t of processing potato tubers [6].

The crude protein (N x 6.25) represents in tubers approximately 2% of a fresh weight that creates approximately 10% of dry matter. However, the crude protein content ranges significantly in dependence on genotype and growing conditions [4]. Crude protein comprises a number of nitrogen fractions; the nutritiously most important of which are protein fraction, amides and free amino acids [7, 14]. Protein fraction (pure protein) represents in average about 50% of nitrogen of potato tubers and may also range from 34% up to 70%. [19]. Increased content of nitrogen component in processing potato cultivars has been so far perceived negatively, because of their easy transition into the waste aqueous by-product of the starch manufactures, so called potato fruit juice (PFJ). On the other hand, non-denatured potato tuber protein isolated from PFJ exhibit promising functional properties, such as the capacity to form and stabilize emulsions and foams [10, 11]. Furthermore, the nutritional quality of potato tuber protein has been shown to be superior to most major plant proteins and close to that of whole egg [2, 11]. Therefore, considerable amount of works has been performed to isolate non-denatured protein concentrates from potato fruit juice [14]. In the Czech Republic can be annually produced about 168 000 - 195 000 m^3 of PFJ when the starch quota is completed and this PFJ contents about 1.5 % of crude protein.

In addition to cultivar [1] content of pure and crude protein may be also affected by environmental and growing conditions (e.g. nitrogen fertilization) [15]. Effect of applied nitrogen on content of crude and pure potato tuber protein was studied intensively mainly for table potato cultivars [2]. These experiments showed positive effect of graded rates of applied nitrogen on content of crude as well as pure protein in potato tubers, although increasing of non-protein nitrogen is much more progressive. On the other hand, graded doses of N fertilization can negatively affect the content of starch in potato tubers [17], especially in connection with high doses of potassium fertilizers [5, 21].

The main objective of this study was to determine the effect of applied nitrogen in connection with cultivar variability and sites differences on content and hectare production of crude tuber protein and other yield characteristics.

MATERIALS AND METHODS

Plant material and field trials

Effect of nitrogen fertilization, cultivar variability and different environmental conditions of selected sites on content of crude protein in potato tuber dry matter was evaluated during the years 2004 and 2005. The field experiments were conducted in the Czech Republic on three sites with different altitudes - České Budějovice (C)

Table 1: Basic soil characteristics on experimental sites
Tabulka 1: Základní půdní charakteristiky na pokusných stanovištích

Site	České Budějovice		Volyně		Lukavec	
Year	2004	2005	2004	2005	2004	2005
$pH/CaCl_2$	5.82	6.10	6.53	6.40	5.84	6.05
N_{total} %	0.14	0.18	0.18	0.19	0.19	0.24
C_{ox} %	1.29	2.85	1.65	4.61	1.77	5.07
P (mg kg^{-1})	89	128	167	128	136	157
K (mg kg^{-1})	71.5	154	221	172	286	185
Mg (mg kg^{-1})	100	123	138	119	212	138
Ca (mg kg^{-1})	1192	1051	2384	1632	1490	1569
N-NH4 (mg kg^{-1})	3.67	1.48	6.10	2.4	4.12	7.09
N-NO3 (mg kg^{-1})	19.1	6.38	39.0	9.88	14.4	5.1

Table 2a, 2b: Crude protein content (% of dry matter) in potato tubers in dependence on year, cultivar and site of growing.
Tabulka 2a, 2b: Koncentrace hrubého proteinu (% sušiny) v hlízách brambor v závislosti na ročníku, odrůdě a stanovišti.

a) year 2004

Cultivar	České Budějovice		Volyně		Lukavec	
	100 N	200 N	100 N	200 N	100 N	200 N
Tomensa	8.99 ± 0.10	9.21± 0.01	8.85 ± 0.01	9.56 ± 0.03	7.07 ± 0.01	8.02 ± 0.08
Rebel	8.67 ± 0.04	9.00 ± 0.11	7.49 ± 0.03	8.97 ± 0.01	8.69 ± 0.04	9.55 ± 0.01
Westamyl	8.43 ± 0.21	8.54 ± 0.49	7.73 ± 0.01	7.86 ± 0.04	7.20 ± 0.001	8.52 ± 0.01
Ornella	9.76 ± 0.05	11.16 ± 0.02	8.80 ± 0.003	9.15 ± 0.08	7.80 ± 0.08	9.31 ± 0.03
Amylon	7.17 ± 0.05	7.65 ± 0.04	6.02 ± 0.003	6.23 ± 0.04	6.17 ± 0.02	7.57 ± 0.01
Kuras	8.00 ± 0.07	7.77 ± 0.10	6.67 ± 0.02	7.68 ± 0.05	6.96 ± 0.43	7.08 ± 0.002
Sibu	7.94 ± 0.13	8.65 ± 0.14	8.17 ± 0.05	7.75 ± 0.02	5.87 ± 0.001	7.85 ± 0.05
Total average	**8.42**	**8.85**	**7.68**	**8.17**	**7.11**	**8.27**

Note: Mean value of measurements for duplicate with standard deviation.

b) year 2005

Cultivar	České Budějovice		Volyně		Lukavec	
	100 N	200 N	100 N	200 N	100 N	200 N
Tomensa	8.31 ± 0.03	8.27 ± 0.14	10.06 ± 0.13	10.88 ± 0.04	7.25 ± 0.09	10.90 ± 0.01
Rebel	7.53 ± 0.02	11.03 ± 0.002	8.60 ± 0.01	9.28 ± 0.05	7.23 ± 0.02	7.84 ± 0.05
Westamyl	6.66 ± 0.04	8.16 ± 0.02	8.50 ± 0.02	8.36 ± 0.04	6.15 ± 0.06	7.83 ± 0.05
Ornella	7.09 ± 0.02	9.31± 0.08	9.48 ± 0.05	9.75 ± 0.01	7.54 ± 0.02	8.11 ± 0.01
Amylon	5.86 ± 0.02	6.77 ± 0.07	7.15 ± 0.02	8.35 ± 0.03	6.63 ± 0.03	6.52 ± 0.05
Kuras	5.90 ± 0.23	7.86 ± 0.05	6.76 ± 0.02	8.40 ± 0.01	5.67 ± 0.11	5.94 ± 0.01
Sibu	6.68 ± 0.03	8.35 ± 0.01	7.58 ± 0.03	7.36 ± 0.04	6.14 ± 0.04	7.22 ± 0.04
Total average	**6.86**	**8.54**	**8.30**	**8.91**	**6.66**	**7.77**

Note: Mean value of measurements for duplicate with standard deviation.

with the altitude 380 m (N 48° 58', E 14° 28'), Volyně (V) with the altitude 460 m (N 49°10´, E 13°54´) and Lukavec (L) with altitude 610 m (N 49° 34´, E 14° 58´). Crude protein contents were determined for seven processing potato cultivars with different maturity class according to the Czech List of Recommended Cultivars [9-8 (very early), 7 (early), 6-5 (semi-early), 4-3 (semi-late), 2-1 (late, very late)]. The cultivars selected for field experiment were following: Tomensa (6 - semi-early maturing), Rebel (7 - early maturing), Westamyl (3 - semi-late maturing), Ornella (3 - semi-late maturing), Amylon (3 - semi-late maturing), Kuras (2 - late maturing) and cultivar Sibu (2 - late maturing). Two variants of nitrogen fertilization, 100 kg N ha^{-1} and 200 kg N ha^{-1}, were used at all three experimental sites. The nitrogen fertilization was applied in the form of ammonium sulphate just before planting and was supplemented with 35 kg P ha^{-1} in the form of hyperphosphate and 60 kg K ha^{-1} in the form of KCl. Narrow-row cereals were always used as the foregoing crop, and manure (40 t ha^{-1}) was applied on the experimental areas in autumn before the experimental season. Individual small plots (4.5 m^2) were arranged in a randomized complete block design replicated three times. Each plot consisted of two 3-m-long rows (planting distance 0.75 x 0.30 m). Plant protection against late blight (Phytophthora infestans) and Colorado beetle (Leptinotarsa decemlinata) was performed by chemical control. Potato crop was not irrigated. Potato tubers were harvested in mature stage and the harvest was made by hand. Twelve average tubers from each of the variant were collected after the harvest for determination of dry matter content and crude protein content. The basic data of experimental conditions are given in Figure 1a, 1b and Table 1.

Analysis of crude protein content and crude protein yield

Potato tubers collected from above mentioned variants of field experiment were washed thoroughly and cut into thin slices which were lyophilized using freeze drier Alpha 1-4 (Martin Christ, Osterode am Harz, SRN). The lyophilized tubers slices were thoroughly homogenized and obtained potato flour was used for crude protein content analysis. Crude protein content was determined as nitrogen in dry matter of potato tubers multiplied by coefficient 6.25. Total nitrogen content was analysed using modified Dumas method on nitrogen/protein analyzer Flash EA 1112 (ThermoQuest, Italy). The average weight of analysed samples was 100 mg and the analysis was made for each the variant in duplicate. The value of crude protein yield per area unit (ha) was calculated on the base of tubers yield per ha and percentage of crude protein content in potato tubers dry matter.

Statistical analysis

Data were analysed with using statistical programme Statistica 6.0 (StatSoft, 2001). The basic method for evaluation of the polyfactorial experiment was four-way analysis of variance (ANOVA). Estimation of the observed factors effect on qualitative and quantitative indicators was performed by the method "Variance components". Conclusive evidence of differences between the averages

Table 3: ANOVA evaluation of polyfactorial experiment - effect (%) of factors year, site, cultivar and N fertilization on the yield parameters.
Tabulka 3: ANOVA hodnocení polyfaktroriálního experimentu - vliv (%) faktorů ročník, stanoviště a dusíkaté hnojení na výnosové parametry.

Studied factors	Tubers yield (t ha^{-1})		Dry matter content (%)		Crude protein content (%)		Crude protein yield (kg ha^{-1})	
	MS	% effect	MS	% effect	MS	% effect	MS	% effect
(1) Year	24682.9***	**41.9**	389.1***	**43.1**	2.5***	0	2657414.7***	**24.09**
(2) Site	6521.5***	8.6	40.4***	2.3	11.1***	2.1	919012.7***	0
(3) Cultivar	1469.8***	9.1	57.5***	**20.3**	19.0***	**34.3**	66863.9***	0.74
(4)N fertilization	80.7	0	12.4***	1.6	34.9***	**17.9**	540941.0***	**8.08**
1*2	3757.6***	**22.6**	38.9***	**14.6**	9.8***	**11.8**	1007551.6***	**41.6**
1*3	240.8***	2.0	7.2***	4.6	1.5***	2.0	77360.4***	4.76
1*4	330.5**	1.0	2.4***	0.4	1.9***	0.7	15867.0*	0
2*3	80.8**	0	4.4***	3.4	0.8***	0	19952.3***	0
2*4	62.5	0	0.2	0	1.4***	0	58971.1***	0
3*4	27.1	0	1.3***	0	0.3***	0	8436.7**	0
1*2*3	89.4**	2.9	1.4***	0.3	1.4***	7.0	15159.7***	3.06
1*2*4	88.4	0.8	0.2	0	1.8***	3.2	55033.7***	4.38
1*3*4	34.3	0.4	1.9***	1.0	0.3***	0	21040.9***	3.25
2*3*4	20.9	0	1.3***	0.2	1.1***	4.3	22396.3***	5.29
1*2*3*4	22.2	0	1.3***	5.8	0.7***	16.4	5227.1*	1.55
Error	31.1	10.7	0.2	0.4	0.01	0.4	2718.4	3.3

Note: Statistically significant on the significance level: * P < 0,05; ** P < 0,01; ***P < 0,001;
without asterix - no significance (Factorial Anova); % effects of the factors were analysed by Variance Components Test (Plot relative variance)

of different levels was tested with assistance of "Post-hoc comparison" (Tukey HSD test).

RESULTS

The presented results have served to establish the relationship between different environmental conditions plus two different levels of nitrogen fertilization and changes in crude protein content in dry matter of processing potatoes, potato tubers yield and crude protein yield per area unit.

Crude protein content

Data obtained from the polyfactorial experiment (Table 2a; 2b) were fluctuated from 5.86 (Amylon, České Budějovice, 2005, variant 100N) to 11.16% (Ornella, České Budějovice, 2004, variant 200N) of crude protein content in dry matter of potato tubers. The most important factor affecting crude protein was cultivar that participated on the total variability with approximately 34% (Table

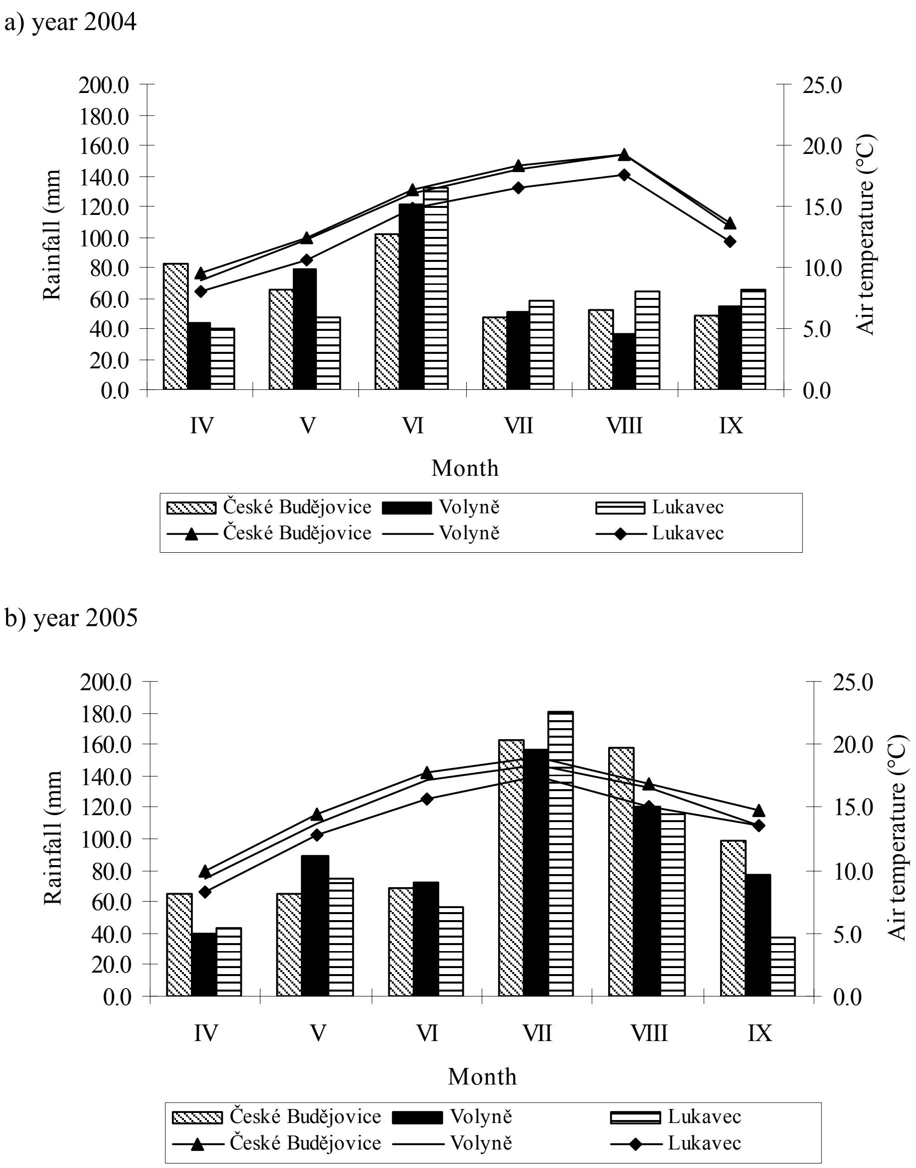

Figure 1a, 1b: Course of temperature and rainfall during the growing seasons on the experimental sites

Obrázek 1a, 1b: Průběh teplot a srážek během vegetace na pokusných stanovištích

3). Effect of nitrogen fertilization was evaluated as the second most important. The effect of site and year was evaluated as the least although the interaction between year and site participated almost with 12% on total variability of crude protein content.

As can be seen from the Table 4, between the year 2004 and 2005 was not evaluated statistically significant difference in crude protein content and the content was at average 8.09 and 7.84 % of dry matter, respectively. Significant difference was found for the site Lukavec, on which was reached the least content of crude protein that was at average 7.45%. The content on the sites České Budějovice and Volyně was higher, reached at average 8.17 and 8.27%, respectively. The significant differences in crude protein content were also evaluated between the cultivars. The cultivar Amylon had the lowest content (6.84%), while the cultivar Tomensa reached at average the highest (8.95%). Also difference between two doses of nitrogen fertilization (100 and 200 kg $N.ha^{-1}$) was statistically significant. Content of crude protein in potato tubers dry matter was higher when used higher dose of nitrogen fertilization causing at average content of 8.42% in comparison with the lower dose causing at average content of 7.51%.

Tuber yield

Potato tuber yield ranged from 16.7 t ha^{-1} (cultivar Tomensa, site České Budějovice, year 2004, variant 200N) to 68.7 t ha^{-1} (Kuras, Lukavec, 2005, variant 100N). The most important factor (Table 3) participating on the yield of potato tubers was the year, affecting the total variability of tuber yield almost from 42%. The second most important factor was interaction between the year and site (almost 23%). How can be seen from the Table 4 the differences in potato tuber yield were statistically significant for all studied factors (year, site, cultivar) with exception of N fertilization. The highest yield of potato tubers was reached in the year 2005 (at average 49.82 t ha^{-1}). The site Lukavec (altitude 610 m) was evaluated as the most optimal site for tubers production - the average yield on this site was 49.7 t ha^{-1}. The effect of higher nitrogen fertilization was not significant and even in the year 2005 the higher nitrogen doses caused lowering of the potatoes production in the case of all used cultivars on the sites Volyně and Lukavec (data not show). In contrast to crude protein content, the yield was significantly affected by the year (Figures 1a, 1b). The year 2004 represented the year with warmer and drier climate; the year 2005 had similar course of temperature although the rainfall was above normal with favourable distribution during the growing season that was probably the main reason of the striking accrual of the tubers production on all three experimental sites.

Crude protein yield per area unit

The crude protein yield per area unit (kg ha^{-1}) was established in dependence on crude protein content in dry matter of potato tubers and yield of potato tubers. How can be seen from the correlation (Figure 2b), the crude protein yield was dependent above all on the yield of potato tubers. The main effect on crude protein yield had combination of year and site (41.46 %) following by other factors such as year (24.09 %) and nitrogen fertilization (8.08 %) (Table 3). The effect of cultivar on the yield of crude protein was minimal. The yield of crude protein ranged approximately from 426 kg ha^{-1} (Amylon, Volyně, 2004, 100N) to 1279 kg ha^{-1} (Kuras, České Budějovice, 2005, 200N). The significant differences in crude protein yield were evaluated for year, site and doses of nitrogen fertilization. Optimal for crude protein yield was the year 2005 (at average 978.7 kg ha^{-1}) and the site Lukavec where was at average produced 994.8 kg ha^{-1} of crude protein. The differences among cultivars were not significant for crude protein yield, although the highest average production was recorded for cultivar Kuras (915 kg ha^{-1}) and the least for cultivar Amylon (755 kg ha^{-1}). The effect of nitrogen fertilization on crude protein production was statistically significant, the higher dose of nitrogen increased yield of tuber protein (Table 4).

DISCUSSION

The effect of nitrogen fertilization and environmental conditions on potato (Solanum tuberosum L.) protein yield and nutritional quality (protein content, nitrate content, amino acids concentration, composition and nutritional quality) is well documented for table potato cultivars [1, 8, 16]. Information about crude protein (N x 6.25) production by processing potato cultivars in specific agro-ecological conditions is also important with respect to the possibility of tuber protein isolation from the aqueous by-product (potato fruit juice) remaining in the starch manufactories [2, 14, 23].

In our experiments crude protein content (N x 6.25) ranged from 5.86 to 11.16% of potato tuber dry matter. These results correspond with findings of other authors [1, 12] who even found out the total crude protein content in wider range from 7.13 to 19.19%. The significant effect of cultivar on crude protein content has been also documented by other authors [1, 3, 20]. The effect of cultivar on crude protein content was in our experiments the most important and presented 34% of crude protein content variability. The positive effect of N fertilization on tuber crude protein content has already been reported [16, 22,] and also confirmed by our experiment. However,

Table 4: Average levels of observed factors in dependence on year, site, cultivar and N fertilization.
Tabulka 4: Průměrné hodnoty sledovaných faktorů v závislosti na ročníku, dusíkatém hnojení, stanovišti a odrůdě.

Factors	n	Potato tubers yield (t ha^{-1})	Dry matter content (%)	Crude protein content (%)	Crude protein yield (kg ha^{-1})
Total	**334**	**41.22**	**26.65**	**7.962**	**853**
Year					
2004	166	32.52 **a**	28.32 **a**	8.09 **a**	727 **a**
2005	168	49.82 **b**	25.54 **b**	7.84 **a**	979 **b**
Site					
České Budějovice	110	34.70 **a**	27.16 **b**	8.17 **b**	746 **a**
Volyně	112	39.15 **b**	25.61 **a**	8.27 **b**	818 **a**
Lukavec	112	49.69 **c**	27.18 **b**	7.45 **a**	995 **b**
Cultivar					
Tomensa	48	34.44 **a**	26.86 **bc**	8.95 **c**	829 **a**
Rebel	48	37.73 **a**	26.12 **ab**	8.66 **c**	841 **a**
Westamyl	48	41.33 **ab**	28.08 **cd**	7.83 **b**	898 **a**
Ornella	47	39.61 **ab**	25.09 **a**	8.94 **c**	868 **a**
Amylon	48	38.22 **ab**	28.91 **c**	6.84 **a**	755 **a**
Kuras	48	51.13 **c**	25.85 **ab**	7.06 **ab**	915 **a**
Sibu	47	46.15 **bc**	25.63 **ab**	7.47 **ab**	866 **a**
Fertilization					
100 N	166	40.86 **a**	26.92 **a**	7.51 **a**	796 **a**
200 N	168	41.58 **a**	26.38 **a**	8.42 **b**	909 **b**

Note: Different letters indicate significant difference on significance level $\alpha = 0.05$ (Tukey HSD test)

direct relationship between N dose and increasing of crude protein content was examined mainly in the year 2004. In the year 2005 was also examined increasing of the crude protein content in dependence on increasing of N fertilization, however this relationship failed and in some cases the crude protein content was lower when used higher dose of N fertilization. This fact was probably caused by the specific course of climate conditions especially substantial rainfalls favourable distributed during the whole growing season. The environmental conditions caused considerable accrual of potato tuber yield and tuber size, which appeared as "dilution effect" causing reduction of both, dry matter content and crude protein content. In addition to the "dilution effect" could be given the decrease of crude protein content by uncommonly low reserve of soil N before planting (Table 1). Content of nitrogen compounds in potato tuber dry matter has been often connected with length of growing season - early maturing cultivars have generally higher content of nitrogen compounds with lower proportion of pure protein [1]. This claim corresponded to our results - the lowest content was at average achieved for cultivar Amylon (3 - semi-late maturing) and the highest for cultivar Tomensa (6 - semi-early maturing).

The climate conditions of the experimental years were also decisive for potato tuber yield. How it was mentioned, the year 2004 represented warmer and drier conditions, which resulted in average yield of 33 t ha^{-1} and the positive effect of nitrogen fertilization on production of potato tubers [3] was explicit on all three sites. The yield of potato tubers also grew with increasing altitude that could be explained by temperature and rainfalls conditions more favourable for production of potato tubers. Climate conditions of the year 2005 were favourable for production of potato tubers and the yield was at the average 49 t ha^{-1}. Although the previously presented relationship [3, 8] between nitrogen fertilization and tuber yield failed, as well as the relationship between altitude and tuber yield confirmed in the year 2004. Average tuber yields of 44, 53 and 52 t ha^{-1} were achieved on the sites České Budějovice, Volyně and Lukavec, respectively. On the sites Volyně and Lukavec was examined the negative effect of higher dose of nitrogen fertilization on tuber yields caused probably by the abnormal rainfalls causing the dose 100N sufficient for filling of the cultivar yield potential.

The effect of N fertilization on potato protein yield and nutritional quality has been well documented in previous publications [16, 8]. The crude protein yield in our experiments ranged from 426 to 1279 kg ha^{-1} which was higher than documented by Honeycutt (1998), however this author used 90 kg ha^{-1} of N fertilization and different cultivars. Considering the dependence of the crude protein yield on the tuber yield the mentioned facts about tuber production appeared also in the case of crude protein yield per area unit. In the year 2004 was confirmed the well-known [3, 8] positive effect of nitrogen fertilization and increasing altitude on crude protein yield per area. Negative effect of N fertilization on tuber yield documented in the year 2005 on the sites Volyně and Lukavec was in the case of crude protein yield examined only on the site Volyně and on the site Lukavec was the lowest tuber yield compensated by the crude protein content in dry matter of potato tubers.

CONCLUSION

Crude protein content and yield per area unit were evaluated in seven cultivars of processing potatoes sampled from field trial conducted during the period 2004-2005 on three sites under two variants of nitrogen

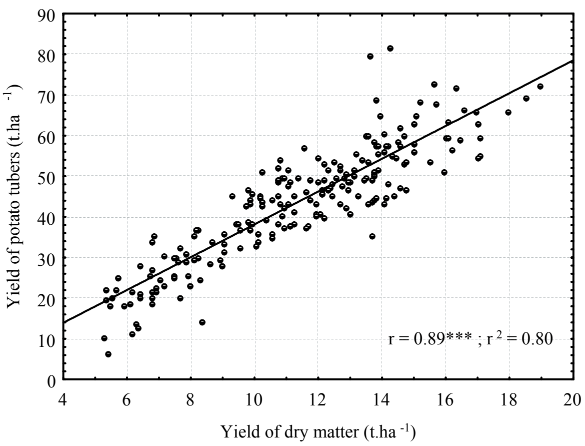

Figure 2a: Relationship between dry matter yield (t ha^{-1}) and tuber yield of processing potato cultivars.
Obrázek 2a: Vztah mezi výnosem sušiny (t ha^{-1}) a výnosem hlíz průmyslových odrůd brambor.

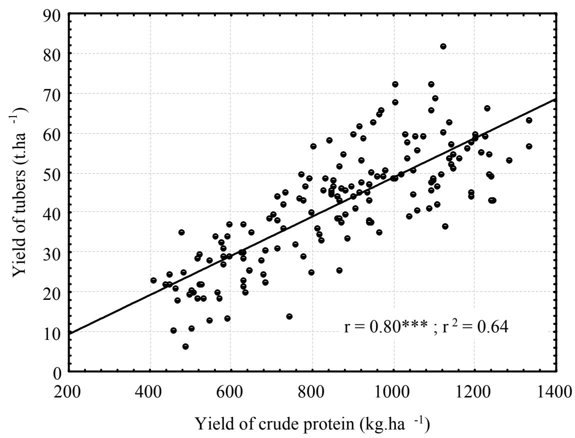

Figure 2b: Relationship between crude protein yield (kg ha^{-1}) and tuber yield of processing potato cultivars.
Obrázek 2b: Vztah mezi výnosem hrubého proteinu (kg ha^{-1}) a výnosem hlíz průmyslových odrůd brambor.

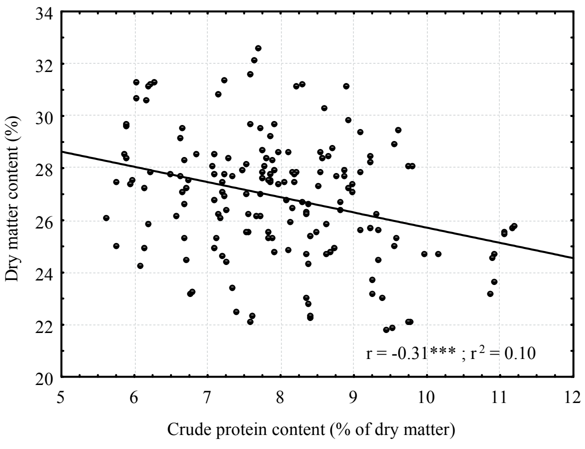

Figure 2c: Relationship between content of crude protein and content of dry matter in potatoes of processing cultivars.
Obrázek 2c: Vztah mezi obsahem hrubého proteinu a sušiny v hlízách průmyslových odrůd brambor.

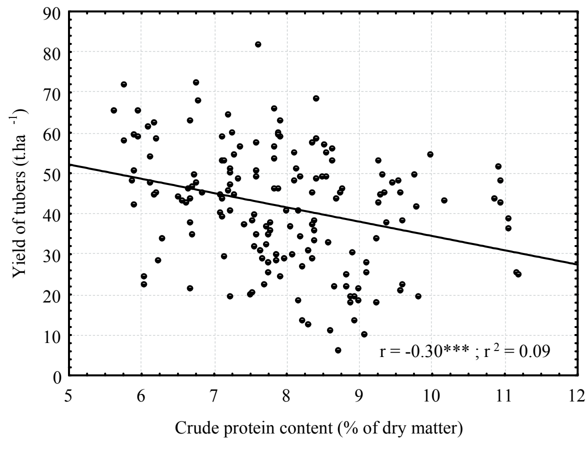

Figure 2d: Relationship between content of crude protein and tuber yield of processing potato cultivars.
Obrázek 2d: Vztah mezi obsahem hrubého proteinu a výnosem hlíz průmyslových odrůd brambor.

fertilization (100 and 200 kg N ha^{-1}). Crude protein content in potato tubers dry matter ranged from 5.86 to 11.16% and was significantly influence by cultivar and nitrogen fertilization. Crude protein yield ranged from 426 to 1279 kg ha^{-1} and was significantly influence by the interaction between sites and year. The increasing altitude caused at average increasing of crude protein yield per area unit, however crude protein content showed opposite trend and the lowest content (7.5%) was achieved on the site with the highest altitude.

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