

The effect of ecological growing on the potatoes yield and quality

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ABSTRACT

In the years 1995–1997 the effect of ecological growing on the yield and selected parameters of quality of consumer potatoes (in comparison with conventional way) were investigated. The ecological way of growing differed in the lack of chemical protection against diseases and pests and industrial fertilizers. Field trials were realised with seven varieties (Impala, Karin, Agria, Korela, Rosella, Santé and Ornella) on two sites (Uhřetěves and Valečov). The ecological way of growing had markedly negative effect on the yield (decrease by 36%). In qualitative parameters the ecological way increased inconclusively polyphenol content (by 10.2%), decreased inconclusively nitrate content (by 11.0%) and reducing sugars (by 22%). It did not affect dry matter content, resistance of tubers to mechanical damage, table value and glycoalkaloid content. Variety Santé achieved the best results from the point of view of the yield and majority of qualitative parameters among varieties. Qualitative parameters of ecologically cultivated potatoes were significantly affected by the year of cultivation.

Keywords: potatoes; ecological and conventional cultivation; quality; yield

Some of the EU countries increase a portion of ecologically cultivated areas. Proportion of ecologically managed areas in the Czech Republic has increased since the 90th. Absence of herbicides, fungicides, insecticides and industrial fertilizers in potato growing has as a consequence a yield reduction of 30% and more (Prosba-Bialczyk 2004). Ecologically cultivated potatoes are supposed by some authors to have lower content of contaminants, better taste qualities, reduced mechanical damage and improved storage stability. On the other hand according to other authors (Maga 1994, Rayburn et al. 1995) plants cultivated without chemicals sometimes protect themselves against diseases and pests by increasing concentration of some harmful substances, e.g. glycoalkaloids and also polyphenols, which represent substrates for enzymic browning of potatoes that occur during peeling, cutting or grating raw potato tubers and together with ferric cations contribute to potato darkening after their cooking (Lachman et al. 2003). Rembalkowska (1999) and Kolsch et al. (1991) determined in contrast with results of the authors Sawicka and Kus (2002) higher dry matter content in potatoes cultivated by ecological way of

cultivation in comparison with the conventional way. From the point of view of nitrate content a majority of the published knowledge notes at least tendency to their lesser content in tubers of ecological alternative or even significant differences (Rembalkowska 1999, Prosba-Bialczyk 2004). Intensive fertilization with nitrogen could even enhance the reduction of sugar and polyphenol content (Peshin and Singh 1999). In consequence of the fertilization with nitrogen also glycoalkaloid content in tubers could increase (Mondy and Munshi 1990). Information about the effect of ecological growing on the reduction of sugar content, glycoalkaloids and polyphenols is noted in scientific literature only minimally and it is not very homogeneous. Hamouz et al. (2000) found in ecologically cultivated potatoes a lower reduction in sugar content. In experiments of Sawicka and Kus (2002) reducing sugar content in the tubers was not affected by the way of growing. Research information about the differences in the quality of conventionally and ecologically cultivated potatoes is neither homogenous nor sufficient, on that account our research was focused on the problems of selected qualitative parameters.

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MATERIAL AND METHODS

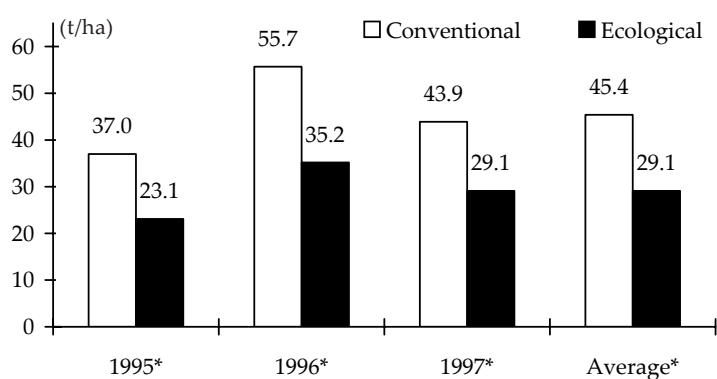
In the years 1995–1997 precise field trials on two sites in Czech Republic were performed. At experimental station of Czech University of Agriculture in Prague-Uhřetěves and on the working area of Research Potato Institute Havlíčkův Brod in Valečov seven varieties of potatoes (Impala, Karin, Agria, Korela, Rosella, Santé and Ornella) were cultivated conventionally and ecologically. In Uhřetěves ecologically cultivated potatoes were incorporated into a model sowing plan according to the principles of IFOAM farming, conventional potatoes were grown in common a sowing plan on an adjacent plot. In Valečov site both variants were incorporated into common sowing plan on the same plot. Winter wheat was in all cases the preceding crop. Differences in growing technology relate to fertilization and use of pesticides. Conventional technology came out from the methodology of state varietal experiments of the Central Institute for Supervising and Testing in Agriculture. Ecological technology differed by the omission of chemical protection against potato blight (with the exception of two applications of cupric oxychloride fungicide on the site Valečov), potato beetle and by deletion of the fertilization with industrial fertilizers. Organic fertilization was the same in ecological and conventional variants: autumn ploughing-in of dung manure 35 t/ha (Valečov) and 30 t/ha (Uhřetěves). Mineral fertilization was used only in conventional option: on both sites 100 kg N/ha, in Valečov 40 kg P/ha and 81 kg K/ha, in Uhřetěves 31 kg P/ha and 73 kg K/ha. Herbicides used in conventional option: Topogard 50 WP (terbutryn + terbuthylazine) 2.5 kg/ha – preemergent application. Insecticides against potato beetle in conventional option: Cymbush 10 DP (cypermethrin) 0.25 kg/ha. Fungicides against potato blight: in conventional option in individual years in different succession preparations Ridomil MZ (metalaxyl + mancozeb) 2.5 kg/ha, Sandofan M8 (oxadixyl + mancozeb) 2.5 kg/ha, Ripost M (cymoxanil + oxadixyl + mancozeb) 2.5 kg/ha, Altima

500 SC (fluazinam) 0.4 l/ha – number of treatment in 1995–1997: Uhřetěves 4, 6, 6, Valečov 5, 6, 7. In ecological option in Uhřetěves any fungicide was not used, in Valečov two treatments with a preparation of Kuprikol 50 (cupric oxychloride) in the dosage 5 kg/ha (4.7. and 16.8.1995; 24.7. and 7.8.1996; 24.7. and 6.8.1997). After the harvest and three weeks' healing period the samples were delivered to the laboratories of Research Potato Institute in Havlíčkův Brod and Department of Chemistry of Czech Agricultural University in Prague for analyses. Tubers resistance against mechanical damage was determined on the electrical pendulum MIDAS 88 PP, dry matter content by gravimetric method, table value by taste degustative test according to Czech State Normative ČSN 462211, reducing sugar content according Luff-Schoorl, nitrate content by ion-selective electrode, polyphenol content spectrophotometrically with Folin-Ciocalteu's reagent, glycoalkaloid content by HPLC method.

RESULTS AND DISCUSSION

Yield. Significantly lesser yield was determined in potatoes cultivated by the ecological way in comparison to the conventional way of growing (Figure 1). Decrease amounted to 35.9% in average of three years, which fully confirms the results of Böhm (1999) and Prošba-Bialczyk (2004). We assume insufficient stock of nutrients in soil and especially the insufficient level of the regulation of diseases and pests perchance weeds as the reason for significantly lesser yields of ecologically cultivated potatoes. Different intensity of the attack of plants in individual years with potato beetle and potato blight proved in reduction or in untimely liquidation of the assimilation apparatus and in a decrease of yield. Santé and Rosella varieties gave the highest average yield response to ecological growing (32.05 and 31.45 t/ha).

Tubers resistance to mechanical damage. Three years of trials with seven varieties did not dem-



$LSD_{0.05}$ = 10.23 (1995), 8.41 (1996), 4.67 (1997), and 4.36 (average)

*significant difference between ways of growing for $P = 0.05$

Figure 1. Effect of the way of growing on the yield (average of 6 varieties from 2 localities)

Table 1. Effect of the way of growing on the qualitative properties of potatoes (average from two localities and seven varieties)

| Way of growing (significance) | 1995 | 1996 | 1997 | Average |
|--|----------|----------|----------|----------|
| Pendulum index (percentage of undamaged tubers) | | | | |
| Conventional | 80.6 | 42.1 | 60.8 | 61.2 |
| Ecological | 77.8 | 43.3 | 53.1 | 59.7 |
| <i>LSD/significance</i> | 10.34/ns | 21.18/ns | 14.20/ns | 8.54/ns |
| Cooking quality (number of point) | | | | |
| Conventional | 56.0 | 63.2 | 61.9 | 60.4 |
| Ecological | 59.7 | 63.4 | 62.8 | 62.0 |
| <i>LSD/significance</i> | 4.13/ns | 8.30/ns | 5.71/ns | 3.32/ns |
| Dry matter content (%) | | | | |
| Conventional | 20.74 | 19.61 | 22.98 | 21.11 |
| Ecological | 20.43 | 20.07 | 21.12 | 20.54 |
| <i>LSD/significance</i> | 0.89/ns | 0.82/ns | 1.58/* | 0.62/ns |
| Nitrate content (mg NO ₃ ⁻ /kg) | | | | |
| Conventional | 215.2 | 105.1 | 140.8 | 153.7 |
| Ecological | 182.5 | 98.2 | 129.5 | 136.7 |
| <i>LSD/significance</i> | 37.65/ns | 27.30/ns | 29.43/ns | 27.37/ns |
| Glycoalkaloids content in cultivar Karin (mg/kg) | | | | |
| Conventional | 112.6 | 53.1 | 65.4 | 77.0 |
| Ecological | 157.0 | 59.2 | 77.5 | 97.9 |
| <i>LSD/significance</i> | 47.0/ns | 35.8/ns | 27.6/ns | 36.9/ns |
| Polyphenols content (mg/100 g) | | | | |
| Conventional | 33.4 | 47.8 | 48.5 | 43.2 |
| Ecological | 40.5 | 51.1 | 51.4 | 47.6 |
| <i>LSD/significance</i> | 7.00/* | 8.90/ns | 5.19/ns | 4.17/ns |

*significant difference *LSD*_{0.05}, ns = non significant

onstrate the effect of ecological growing on this parameter of tubers quality. Differences among values of pendulum index (indicates percentage of undamaged tubers on pendulum) between ecological and conventional option did not reach in any year the value of minimal significant difference (Table 1). Nitrogen dose 100 kg N/ha in our experiments did not affect unfavourably maturity of tubers and in consequence of this also not their resistance to mechanical damage. Also in experiments of Diviš and Štěrba (1997) event the dose 120 kg N/ha did not enhance the level of mechanical damage. It is possible to presume that only relatively high N doses (depending on the variety

different) could have unfavourable effect on the resistance of tubers against damage.

Table value. The way of growing did not affect demonstrably table value of tubers; only in 1995 tendency (not a significant difference) to higher table value in potatoes from ecological cultivation was determined (Table 1). Kolsch et al. (1991) came to similar information. Certain tendency in 1995 to higher table value in potatoes from ecological cultivation could have association with low average mass of consume tubers in Uhříněves in this year (the lowest yield of tubers among all experimental years 13.12 t/ha in consequence of extensive over-running with seeds, damage of haulm by Potato

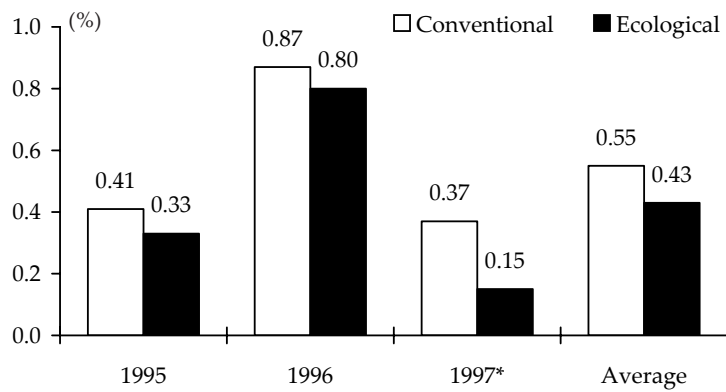


Figure 2. Reducing sugar content in % of tubers' fresh matter affected by the way of growing (average of 4 varieties from 2 localities)

$LSD_{0.05}$ = 0.14 (1995), 0.12 (1996), 0.21 (1997), and 0.13 (average)

*significant difference between ways of growing for $P = 0.05$

beetle and consequently very dry weather in July). Tubers size affect according to our experience firmness of tubers pulp after cooking (higher firmness in lesser tubers) and cooking properties of tubers (higher softness on cooking is in bigger, esp. over-ripened tubers). Karin and Santé proved regularly the best table value.

Dry matter content. Our results did not approve the increase of dry matter of tubers in ecological way of growing as Rembialkowska (1999) and Kolsch et al. (1991) state. In the years 1995 and 1996 the differences between variants of our experiment were not significant (Table 1). In the year 1997 higher dry matter content was determined in the conventional variant. The obtained outcome from the year 1997 is in accordance with knowledge of authors Sawicka and Kus (2002), who determined higher dry matter content in potatoes from integrated system of farming in comparison with the ecological way. Our results show that nitrogen and potassium applied in conventional variant on given localities did not lower dry matter content. It is related apparently with the fact that at common doses of nitrogen and potassium fertilizers, which we applied in our experiments, the changes of dry matter content are little. And on the contrary oftentimes a shorter period of existence of assimilation apparatus of ecological variant (in consequence of its destroy by potato beetle or blight) could have as a consequence a decrease of dry matter content in this variant. This explicates our result from the 1977-year (lesser dry matter content in ecological variant, when the haulm was prematurely destroyed by potato beetle). The highest dry matter content in ecologically cultivated potatoes in the average of three years was observed in industrial Ornella variety (24.8%) and in consumer potatoes in Santé variety (21.9%).

Reducing sugar content. Trend (non significant difference) to lesser reducing sugar content in the three year average results in potatoes from ecological growing in comparison with conventional variant was determined (Figure 1). It was confirmed

by the significant result from the 1997-year. Our result is regarding the nitrogen dose only partially comparable with the information of authors Peshin and Singh (1999) who determined that intensive nitrogen fertilization could bring an enhanced sugar content reduction, which our results partially explains. In the experiments of Sawicka and Kus (2002) reducing sugar content did not depend on the way of cultivation. In the ecological way of cultivation the best result in Agria, Ornella and Santé varieties (0.21, 0.22, 0.48% reducing sugars) was determined.

Nitrate content. Our experiments did not prove the effect of the way of growing on nitrate content, but in all years an apparent trend to its less values in potatoes from ecological cultivation appeared (Table 1). The determined trend is in accordance with published results, which in predominant majority state at least tendency to lesser nitrate content in the tubers of ecological variant and many times also significant differences (e.g. Kolsch 1991, Rembialkowska 1999). In our experiments we recorded relatively considerable difference in nitrate content between the ways of cultivation (tightly under the level of significance) in 1995, but in next two years the differences were much lower. It was evidently related with early termination of vegetation by potato beetle in ecological (chemically non treated) variant. To this situation came in 1996 and 1997 years in the period of full vegetation, when the tubers were not ripe and nitrates were in lesser extent incorporated into other compounds. Agria (58.5 mg NO_3^-/kg) and Santé (79.8 mg NO_3^-/kg) varieties in three years the average results in ecological cultivation reached the lowest nitrate content.

Glycoalkaloid content. Analyses were performed only in Karin variety. No significant difference in glycoalkaloid content was determined in potatoes cultivated by the ecological way of growing in comparison with the conventional way in any investigated year. The trend of higher glycoalkaloid content in ecological variant was found only in the

year 1995 (Table 1). In this year higher glycoalkaloid content was recorded on the site Uhříněves, where the crop vegetation was harvested prematurely in consequence of total defoliation by potato beetle. Likewise in the experiments of Peksa et al. (2002) earlier term of harvest had in consequence higher glycoalkaloid content in tubers. In our trials in ecological variant hygienically allowed limit 200 mg glycoalkaloids/kg fresh matter of tubers was not exceeded in any year. The obtained results also confirm the possibility of a low glycoalkaloid content with nonconventional breeding approaches of new potato genotypes on the basis of interspecific hybrids (Esposito et al. 2002).

Polyphenol content. Higher total polyphenol content was shown in potatoes from ecological growing (Table 1). Similar results we have obtained also in our previous work (Hamouz et al. 1997). The result could be related to the reaction of chemically non-treated plants against different stress factors (in our case potato beetle feed-mark, infection with blight). Between two assessed varieties lesser polyphenol content in Agria variety in comparison with Karin variety in ecologically cultivated potatoes were found (in individual years by 16.5, 6.5 and 5.6%).

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ABSTRAKT

Vliv ekologického pěstování na výnos a kvalitu brambor

V letech 1995–1997 byl sledován vliv ekologického pěstování na výnos a vybrané ukazatele kvality konzumních brambor (v porovnání s konvenčním způsobem). Ekologický způsob pěstování se lišil vynecháním chemické ochrany proti chorobám a škůdcům a průmyslových hnojiv. Pokusy byly realizovány se sedmi odrůdami (Impala, Karin, Agria, Korela, Rosella, Santé a Ornella) na dvou lokalitách (Uhříněves a Valečov). Ekologický způsob pěstování měl

výrazně záporný vliv na výnos (pokles o 36 %). Z kvalitativních ukazatelů ekologický způsob zvýšil neprůkazně obsah polyfenolů (o 10,2 %), snížil neprůkazně obsah dusičnanů (o 11,0 %) a redukujících cukrů (o 22,0 %), neovlivnil obsah sušiny, odolnost hlíz k mechanickému poškození, stolní hodnotu a obsah glykoalkaloidů. Z odrůd dosáhla v ekologickém pěstitelském systému nejlepších výsledků z hlediska výnosu i většiny kvalitativních parametrů odrůda Santé. Kvalitativní parametry ekologicky pěstovaných brambor byly výrazně ovlivněny ročníkem.

Klíčová slova: brambory; ekologické a konvenční pěstování; kvalita hlíz; výnos

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