

THE ROLE OF ENVIRONMENT AND WAY OF CULTIVATION IN REDUCING SUGAR CONTENT OF POTATOES*

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In the years 1995 to 1997 field trials were conducted to study the effect of soil-climatic conditions of the regions of different altitude, variety, year of cultivation and ecological cultivation on reducing sugar content (RS) in fresh tuber matter. Significantly lower RS content was determined from three years' trial in potatoes from drier and warmer low-situated regions (0.44%) compared with more humid and cooler traditional potato-growing regions from higher altitudes in the Czech Republic (0.56%). The variety had the significant effect on the RS content. The varieties Ornella (0.26%) and Agria (0.37%) out of four investigated varieties differed significantly with lower RS content from the varieties Santé (0.61%) and Rosella (0.72%). The year of cultivation had the greatest effect on RS content. Significant differences in RS content were found among individual investigated years, in which average value varied from 0.22% (1997) to 0.81% (1996). A definite decrease in RS content was demonstrated in the ecological cultivation in comparison with the conventional growing that varied between 8% (1996) and 59% (1997). The difference was significant only in the year 1997.

potatoes; reducing sugars; environment; ecological growing; variety; year

INTRODUCTION

Two types of reactions are present during the heat processing of potatoes (frying, baking, drying) that cause undesirable the so-called non enzymic browning, i.e. caramelisation and the Maillard reaction (Kadam et al., 1991a). Specific sugar degradation (caramelisation), in which also sucrose is degrading in higher degree, according to the energy demand during frying at higher temperatures (220 °C), was exerted in lesser amount. The Maillard reaction between reducing sugars (RS) and amino acids is more important for colour changes. Browning of sugars takes place at usual temperatures of frying (165–170 °C) only in the presence of amino acids. More distinctive browning can be observed at temperatures about 100 °C in the process of drying of potato pulp and during the long-term storage processing of potato products at usual temperature (Burton, 1989). α -amino compounds appear in potatoes only rarely as a limiting factor and therefore an intensity of colour changes is depending on the reducing sugar content (Kadam et al., 1991a). Poppr et al. (1995) found a high correlation ($r = -0.8965$) between the potato chip colour and reducing sugar content. Rodriguez-Saona, Wroldstad (1997) have found that reducing sugar concentration cannot completely explain or predict the colour quality of chips when it would be present in low concentrations (approximately $< 0.06\%$). Multiple

correlation analysis of their results showed a negative association of fructose ($r = -0.7$) and glucose ($r = -0.7$) with potato chip colour.

Non-enzymic browning reactions are important especially for fried products from practical point of view. The prevention of colour changes depends especially on selection of suitable raw material for processing. Supported maximal reducing sugar content in potatoes for chips production could not be higher than 0.2% and in contrary for obtaining of desired colour it could not be lower than 0.1%. In the case of potato crisps the maximal supported reducing sugar content is higher – bellow 0.8% (Kadam et al., 1991b). Against these facts Burton et al. (1992) consider for maximally acceptable level for chips 0.25–0.3% RS and for crisps about 0.5% in fresh tuber matter. According to Lisinska (2000) RS content in tubers for production of crisps should not exceed 0.25%, for production of chips 0.3% and for production of mashed potatoes 0.5%.

RS content (especially glucose and fructose) is influenced by many factors and is very closely connected with saccharide metabolism (Manrique-Klinge, 1998). Putz and Lindhauer (1994) have found that the amount of reducing sugars in potatoes is highly influenced by selection of variety, stage of maturity, and storage. Also Jakuczun et al. (1995) confirm that the reducing sugar content is in a great deal significantly affected by the year of evaluation, storage temperature

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and genotype. Putz (1995) has obtained results showing that the content of reducing sugars decreased with maturity. Burton et al. (1992) described that high RS content could be found immediately after the harvest and curing period. However, in many cases it increased during the storage period. These authors arbitrarily divided the factors affecting reducing sugar content into major effects (cultivar, maturity, storage temperature, reconditioning) and minor effects (soil composition, fertilisation, environment, water supply). Poppr et al. (1995) have found a negligible increase reducing sugar content at the storage temperature 8–10 °C at the end of a storage period but the lower storage temperature (2–3 °C) was associated with a greater accumulation of reducing sugars. Zgórska, Frydecka-Mazurczyk (1982) have found that even in warm years of cultivation reducing sugar content decreased. On the contrary, sufficient water supply and low temperatures during vegetation and high nitrogen fertilising amounts increased the sugar content. In later experiments these authors documented significant relation between RS content and precipitation and temperatures at the end of vegetation period (last 10 days before harvest). Great sums of precipitation and low temperatures caused the secondary growth of tubers in some years and the increase of RS content (Zgórska, Frydecka-Mazurczyk, 2000).

It is known from literature that RS content is affected by storage, variety, factors determined by weather, conditions of given locality, and the way of cultivation. Results obtained for a concrete influence of the given factors are not always explicit. The aim of this research was to compare the RS content in potatoes cultivated under different soil and climatic conditions of traditional potato growing regions and lower situated regions of CR where in the 1990s years was a significant increase of areas where throwaway potatoes are cultivated. Another aim was to determine the effect of ecological cultivation and

to investigate the varietal differences and effect of a given year of cultivation.

MATERIAL AND METHODS

In 1995 to 1997 field trials were carried out on twelve localities in CR where the varieties Agria, Ornella, Santé, and Rosella potato varieties were cultivated according to unique farming techniques. Six localities were situated in lower, warmer and drier regions with fertile predominantly loam soils (Orthic Luvisol and black Luvic Chernozem prevailed) and in this contribution they are indicated by the common term "lower regions". Other six localities were situated in higher, cooler and more humid regions with less fertile predominantly sandy loam soils (Cambisol is predominating) and it represents the traditional potato growing regions in CR. In our contribution we have indicated them as "higher regions". On two localities besides the conventional cultivation of potato the other variant was comprised in the experiments – growing in accordance with the ecological cultivation without chemical protection and industrial fertilisers. Table 1 shows the rainfalls and temperature values in investigated vegetation periods and in the most important period for tuber maturity. Tubers of the mentioned varieties of all localities after the harvest and on average of four weeks curing period were stored for 12 weeks period (in the year 1996 for 14 weeks) at 5 °C and investigated continuously. Unpeeled potato tubers of medium size were used for preparation of samples. To detect the RS content tubers were analysed according to the Luff-Schoorls' method (Dáviděk et al., 1977). Results were calculated from four parallel analyses of each sample. Statistical methods: SAS 6.12 package (the method ANOVA, Tukey test) were used for statistical evaluation of the results obtained. The values of the least significant difference are presented in the text below the figures.

Table 1. Characteristics of weather in vegetation period in the years of cultivation

Year	Region	Average temperature (°C)			Sum of precipitation (mm)		
		August	September	April–September	August	September	April–September
1995	LR	18.92	13.57	15.63	90.6	82.4	439.9
	HR	16.15	11.80	13.42	100.2	113.0	527.7
	average	17.53	12.68	14.53	95.4	97.7	483.8
1996	LR	18.23	11.10	14.57	73.3	53.1	463.5
	HR	16.12	9.02	12.40	97.1	69.0	490.9
	average	17.18	10.06	13.48	85.2	61.1	477.2
1997	LR	19.90	13.98	15.02	46.9	29.3	391.8
	HR	18.02	12.70	13.12	33.6	25.6	487.9
	average	18.96	13.34	14.07	40.2	27.3	439.8
Long-term average	LR	18.03	14.28	15.15	71.5	45.4	360.1
	HR	15.83	11.23	12.73	83.2	52.2	424.7
	average	16.93	12.76	13.94	77.3	48.8	392.4

LR – lower regions (average of 6 localities), HR – higher regions (average of 6 localities), average – average of all 12 localities

RESULTS AND DISCUSSION

The effect of region

From all investigated factors the region has shown to have the lowest effect on RS content what was documented with calculated *F* values: regions 10.42; varieties 37.12; years 104.11. Potatoes cultivated in lower regions in all investigated years contained lesser RS amounts in comparison with potatoes originated from higher situated regions, meanwhile the difference of RS contents in potatoes from both regions was in the years 1995, 1996 and in three years average statistically significant (Fig. 1). Our trials have shown that in cooler and more humid conditions of higher regions potatoes accumulate more RS in tubers. It is generally known that warmer and drier conditions affect positively maturation of tubers (Hruška et al., 1974). Therefore potatoes cultivated in higher altitudes have often less mature tubers at harvest in comparison with the same varieties cultivated in lower altitudes. This fact was found in our trials, in which we recorded significantly higher temperature averages in lower regions and lower rainfall sums during vegetation period in comparison with higher situated regions. This was found also in August and September when potatoes matured. Exceptions formed moderately higher rainfall sums in lower situated regions during the end of vegetation in 1997 that was extraordinary dry (Table 1) in both regions. Lower average tuber maturity from higher regions demonstrates also their lesser resistance against mechanical damage. This is documented by the results obtained with tests on Electronic Pendulum MIDAS 88PP that were performed after the harvest (Table 2). Higher RS content coheres with lower tuber maturity as it was reported by e.g. Putz, Lindhauer (1994), Burton et al. (1992), Putz (1995), Poppr et al. (1995) and Zgórska, Frydecka-Mazurczyk (2000).

Effect of variety

The variety had a significant effect on RS content (Fig. 2). The varieties Ornella followed by Agria demonstrated the lowest accumulation out of four used varieties on average of three years. The difference in RS content in the variety Agria compared with the variety Ornella variety was not significant. In these varieties we also recorded the highest stability (the minimal differ-

Table 2. Percentage of undamaged tubers (pendulum index) on pendulum MIDAS 88 PP (average of all 4 varieties from 6 localities of every region)

Region	Years			
	1995	1996	1997	average 1995-1997
Higher	81.65	47.73	59.33	62.90
Lower	90.75	62.65	69.20	74.20

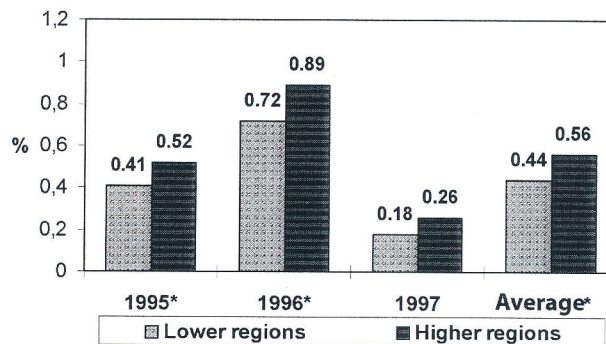


Fig. 1. Reducing sugar content in fresh potato tubers (%) affected by environmental conditions of growing region (average value of four varieties and 6 localities of every region). $LSD_{p 0.05} = 0.09$ (1995); 0.16 (1996); 0.09 (1997); 0.07 (average)

* significant difference between growing regions for $P = 0.05$

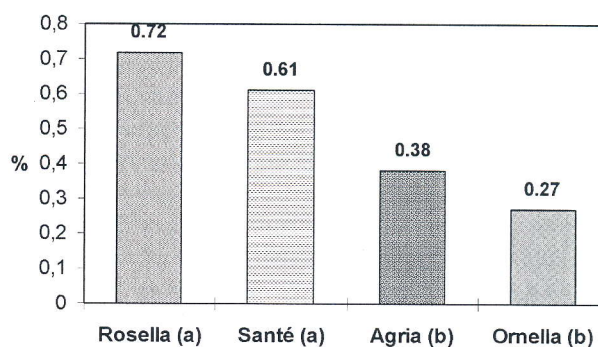


Fig. 2. Reducing sugar content in fresh potato tubers (%) affected by variety (average value from 12 localities). $LSD_{p 0.05} = 0.12$. Differences among varieties designated with the same letters are not statistically significant

ence between minimum and maximum RS contents in tubers). RS content in the Santé and Rosella varieties was significantly higher in comparison with the values determined in the Ornella variety and the differences in both varieties were significant compared with the results obtained for Ornella and Agria varieties.

The Ornella and Agria varieties belong in CR to well-established varieties for processing of qualitative fried chips. In spite of this fact in some cases of our experiments they did not satisfy the demand for maximally acceptable RS level for obtaining of attended colour. That level is shown in range from 0.2 to 0.3% (Kadam et al., 1991b; Burton et al., 1992; Lisinska, 2000) of fresh tuber mass. It could be explained by the medium-term period storage of our samples at the temperature 5 °C what is in accordance with the results described in the literature (Poppr et al., 1995). This storage has apparently caused certain RS content increase in all varieties. Our experiments confirmed significant effect of the variety on RS content what was referred by many authors (Putz, Lindhauer, 1994; Jakuczun et al., 1995; Poppr et al., 1995; Zgórska, Frydecka-Mazurczyk, 2000). The variety has shown greater effect on RS content than a region.

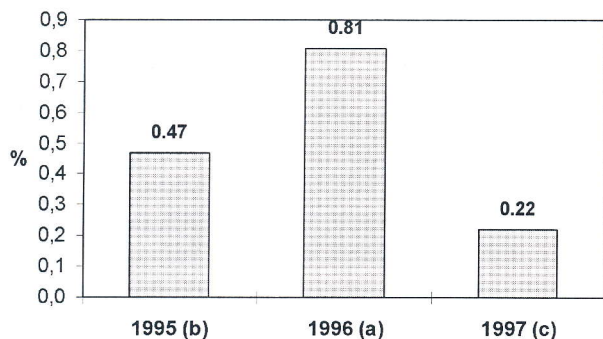


Fig. 3. Reducing sugar content in fresh potato tubers (%) affected by year (average value of four varieties from 12 localities). $LSD_{p,0.05} = 0.10$. Differences among years designated with the same letters are not statistically significant

The effect of year of cultivation

The effect on RS content year of cultivation was the most significant of all investigated factors. Individual years have significantly differed among themselves (Fig. 3). Significantly highest RS content was recorded in 1996, when it reached 172% of the value of 1995 and 368% of the value of 1997. This result could be correlated with worse tuber maturity from our experiments in 1996 when the lowest average temperature from three years' trials was recorded during vegetation period and above all very cool September with average temperature 2.7 °C below the level of long-term average (Table 1). Rainfalls in the final period of vegetation of this year were moderately above long-term average. Similar weather characteristics in the last vegetation phase of potatoes (low temperature, high amounts of precipitation) increased RS content (above 0.5%) also in the experiments of Zgórska, Frydecka-Mazurczyk (2000). Indirect proof of the minimal maturity of tubers in our experiment in the year 1996 is the minimal resistance to mechanical damage in this year as compared with all investigated years (Table 2). On the contrary, low RS content in 1997 could be attributed to very warm and dry end of vegetation, when average month temperature in August exceeded long-term average by 2.03 °C and in September by 0.58 °C. Rainfalls reached in August only 52.1% and in September 56.4% of long-term average values (Table 1). Significant effect of the year of cultivation on RS content that appeared in our experiments was in correspondence with the results obtained by Jakuczun et al. (1995), Poppr et al. (1995) and Zgórska, Frydecka-Mazurczyk (2000) lesser meaning of this factor was recorded by Burton et al. (1992).

The effect of ecological growing

In potatoes cultivated in ecological cultivation the tendency to lower RS content in three years' average of the results and in 1995 and 1996 was determined. In 1997

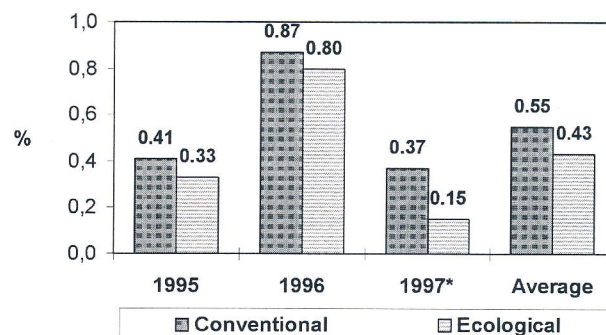


Fig. 4. Reducing sugar content in fresh potato tubers (%) affected by way of cultivation (average value of four varieties from 2 localities). $LSD_{p,0.05} = 0.14$ (1995); 0.12 (1996); 0.21 (1997); 0.13 (average)

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

the difference in RS content between these two technologies was actually significant (Fig. 4). The results obtained could be in connection with absence of nitrogen fertilising in ecological variant because it is generally known that application of nitrogen fertilisers could share on protraction of vegetation period and delaying of physiological maturity of potatoes. Zgórska, Frydecka-Mazurczyk (1982) determined that high levels of nitrogen increased sugar content in tubers. In addition, Sawicka, Mikos-Bielak (2000) recorded considerable varietal differences as the reaction to nitrogen fertilization.

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Role prostředí a způsobu pěstování na obsah redukcujících sacharidů v bramborách.

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Byl sledován obsah redukcujících cukrů (RC) v hlízách brambor vypěstovaných v rozdílných půdně-klimatických podmínkách tradičních bramborářských oblastí ČR (vyšších poloh) a nižších poloh, kde v 90. letech došlo k nárůstu ploch konzumních brambor. Dále byl sledován vliv ekologického způsobu pěstování, vliv ročníku a odrudové rozdíly. Přesné polní pokusy se čtyřmi odrudami se uskutečnily v letech 1995 až 1997 na šesti stanovištích každé oblasti. Hlízy byly po sklizni a po průměrném čtyřtýdenním hojivém období skladovány při teplotě 5 °C po dobu 12 (v roce 1996 14) týdnů až do rozborů na obsah RC. Byl zjištěn průkazně vyšší obsah RC u brambor z vyšších poloh. To souvisí s horší vyzrálostí hlíz v době sklizně, která se v našich pokusech častěji projevila u brambor z vyšších poloh. Významný vliv na obsah RC měla odrůda. Ze čtyř použitých odrůd nejméně kumulovaly redukcující cukry odrůdy Ornella a Agria, u odrůd Santé a Rosella byl v porovnání s nimi zaznamenán průkazně vyšší obsah RC. Nejvýraznější vliv na obsah RC ze sledovaných faktorů měl ročník. Výrazně nejvyšší obsah RC byl zjištěn v roce 1996, kdy nízké teploty ve vegetačním období a zejména velmi chladný měsíc září s průměrnou teplotou o 2,7 °C pod úrovní dlouhodobého průměru při mírně nadprůměrných srážkách negativně ovlivnily vyzrállost hlíz při sklizni. Naopak nízký obsah RC v roce 1997 přičítáme velmi teplému a suchému závěru vegetace. U brambor z ekologického pěstování byl zjištěn v tříletém průměru výsledků trend k nižšímu obsahu RC v hlízách proti bramborám vypěstovaným konvenčními technologiemi.

brambory; redukcující cukry; podmínky prostředí; ekologické pěstování; odrůda; ročník

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