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Effect of cultivar, location and year on total starch, amylose, phosphorus content and starch grain size of high starch potato cultivars for food and industrial processing

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ABSTRACT

In recent time the interest of industry increases particularly in processing and use of potato high amylopectin (AMP) starches. Therefore the plant breeders effort to obtain “waxy” potato cultivars with low amylose (AMS) content. In this four-year study sixteen potato cultivars grown on five experimental locations were evaluated on the percentage of AMS/AMP by enzymatic method, starch content by the underwater weight method, phosphorus (P) content in starch digests spectrophotometrically, and starch granule size determined by laser diffraction method. Between enzymatic and iodine–potassium iodide method good correlation has been revealed ($r = 0.71$). The correlation analysis between AMS and P levels showed a clear negative correlation. For all measured parameters (starch, AMS, P, starch granule size) significant impact of cultivar has been determined. Location and year have lower, but significant impact. No statistically significant effect of year on AMS has been found. The cultivar Amado distinguished with the highest AMP and P contents and the cultivar Westamyl showed all positive values interesting for growers and processors.

1. Introduction

Potatoes (*Solanum tuberosum*) are one of the most important crops to feed the world population. At the same time it is an important commodity for industrial process and production of starch. Starch occurs in most plants, but only from a small number of species can be virtually obtained. In the Czech Republic starch is made mainly from potato (about 60%) and wheat (40%). In the world production corn starch prevails. The main producer of corn starch is the USA with an annual production of 25 million tons of corn starch. Wheat and potato starch are produced mainly in EU countries (1.8 million tons of potato and 2.8 million tons of wheat). EC Regulation 1868/1994 and its following amendments establish a total quota for potato starch production in EU 25 of 1.949 million tons. This corresponds to a quota of 1.762 million tons of starch for starch producing Countries of EU 15 (i.e. Denmark, Germany, Spain, France, the Netherlands, Austria, Finland and Sweden) and 0.187 million tons of starch for the new Member States after 2004 enlargement (Czech Republic, Estonia, Latvia, Lithuania, Poland, Slovakia). The importance of starch in potatoes is assessed in terms of the quantity and physico-chemical properties (Vasanthan, Bergthaller, Driedger, Yeung, & Sporns, 1999). Potato tubers as the only usable part of the plant contain up to 25% starch in fresh mass (Čermák, 2012). The ratio of amylose (AMS) and amylopectin (AMP) fractions determines not only the properties of starch, but also its end use and application in food and a wide range of industries. Separation of the two components in industrial processing is costly, and leads to a high proportion of waste water. Therefore, potato breeding is driven by a change in the share of both components of and thus more possibilities of starch, e.g. in food industry and in the field of protective packaging, films, fibres, to the formation of biologically degradable materials of varying degrees of degradation.

In the studies of starch isolated from potato cultivars grown at the locations in Canada the analytical results suggest that differences in chemical composition and molecular chain length of potato starch may contribute to different functional properties of potato dry matter and starch of individual cultivars (Liu, Tarn, Lynch, & Skjodt, 2007; Lu et al., 2011). The comparison of the physicochemical properties of normal potato, waxy potato, yam and sweet potato starches revealed the absolute AMS contents of the four starches were normal potato, 18.3%; waxy potato, 0%; yam, 17.7%; and sweet potato 22.8% (McPherson & Jane, 1999). The

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physico-chemical, morphological, thermal, pasting, textural, and retrogradation properties of the starches isolated from four traditional Taewa (Maori potato) cultivars of New Zealand were studied and compared with starch properties of the modern cultivar Nadine, and significant differences were observed using Pearson correlation (Singh, McCarthy, & Singh, 2006).

For food processing purposes there are appreciated potatoes with higher AMS content unlike potatoes used for non-food industry containing higher AMP levels in starch. Therefore the aim of this study was designed to the evaluation of selected high starch potato cultivars on the basis of their starch, AMS/AMP, P contents and starch granule size and assessment of impacts of potato cultivars, cultivation locations and years on analysed parameters. Part of the study was the assessment of two methods – enzymatic and iodine/potassium iodide used for determination of AMS. The study was focused on the choice of potato cultivars useful for food and processing industry starch production.

2. Materials and methods

2.1. Plant material

In the experiment sixteen selected potato starch cultivars (Table 1) grown on five locations in the Czech Republic with different climatic conditions (Table 2) in the years 2005–2008 were investigated. The analyses were carried out in the Laboratory of Analytical Chemistry of the Potato Research Institute in Havlíčkův Brod.

2.2. Field experiments method

All potatoes were cultivated according the same method: as a pre-crop cereals or green-manure; fertilisation with 35 t/ha manure in the autumn supplemented with phosphate and potassium (magnesium) fertilisers (dose with regard to the supply of nutrients in the soil): nitrogen (120 kg/ha) of soil in preparation for spring. Experimental area: 13.950 m^2 (2 lines of 32 clusters, i.e. 1.5 m × 9.30 m = 64 clusters on the plot); ties of planting: 0.75 m (spacing) × 0.29 m (distance of plants); seedlings: size 35–45 mm, sprouting, and 15 kg for a location for each cultivar. Cultivation: harrowing and pre-emergence herbicide application, potting; protection with regard to weeds and pests registered products; monitoring of vegetation: the final number of clusters on a plot and condition of the plants in flower (height, uniformity, coverage, total state); harvest: each part separately with findings yield per plot; sampling: 25 kg. Experiments were performed in three replicates. Uniform-size potatoes were selected from each cultivar before starch isolation.

2.3. Starch isolation

For starch isolation modified method of Singh and Singh (2001) was used. Potatoes were washed carefully in tap water, brushed and peeled. The eyes and all bruises were pitted out. For the actual process half of each potato tuber was used. Separation of tubers was carried out in the longitudinal direction from the stolon end to the apical end of tubers. On the laboratory grater approximately 1.5 kg of potato tubers was processed. Grated tubers were poured with 5 L of distilled water and left to stand with occasional stirring for 4 h. Thereafter, after decantation, the starch was washed with distilled water through the filter into the sedimentation beaker. Starch sediment in the vessel was stirred and then filtered through a sieve (mesh 125 μm), which captured the remainder impurities. Thereafter, the beaker containing filtrate with starch suspension was kept undisturbed to settle overnight. The next day supernatant liquid was carefully decanted and to the sediment 2 L of distilled water was added, stirred and left to settle overnight. A solid layer of starch settled down. The supernatant liquid was decanted, the starch layer was reslurried in distilled water and, again, starch was allowed to settle. This was repeated 4–5 times until the supernatant became transparent. Starch was then left to dry in the beaker for 2–3 days. Starch cake was then collected onto the filter paper and for several days freely dried at room temperature to constant weight. The samples were finally lightly pulverised and kept in resealable air-tight plastic bags at room temperature until further use.

2.4. Determination of starch dry matter

Starch dry matter was obtained according to the method of Liu, Weber, Currie, and Yada (2003). Five grams starch samples were dried for 90 min at 130 °C and after cooling in the desiccator weighed and dry matter calculated as a percentage dry matter content.

2.5. Starch mineralisation

Mineralisation of starch samples was carried out in CEM MARS 5 microwave digestion oven for samples decomposition (CEM Corporation, Matthews, NC, USA). Conditions of decomposition: 0.5 g sample of starch (dried at 130 °C for 90 min) + 2 mL of conc. HNO_3 (p.a.) + 5 mL of distilled water; temperature 160 °C; degrada-

Table 1
Basic characteristics of analysed potato cultivars.

Cultivar	Classification according the vegetation period scale of the CISTA[a]	Intended use according to the CISTA[a]	Country of origin
Albatros	4–5 – semi-early	Chips, starch	Germany
Apolena	3 – semi-late	Chips	Czech Republic
Amado	2 – very late	Starch	Germany
Ikar	1 – very late	Starch	Poland
Krumlov	2 – very late	Starch, pommes-frites	Czech Republic
Kuras	1 – very late	Starch	Netherlands
Nomade	6 – semi-early	Starch	Netherlands
Orbit	6 – semi-early	Chips, starch	Germany (nonregistered)
Ornella	3 – semi-late	Starch, pommes-frites	Czech Republic
Rebel	6 – semi-early	Starch	Czech Republic
Roberta	4 – semi-late	Starch	Germany
Sibu	2 – late	Starch	Germany
Sonate	3 – semi-late	Table, dry potatoes, chips	Germany
Tomensa	6 – semi-early	Pommes-frites, starch	Germany
Vladan	5 – semi-early	Pommes-frites, starch	Czech Republic
Westamyl	3 – semi-late	Starch	Czech Republic

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