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Structural, thermal and viscoelastic properties of potato starches

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Abstract

The starches separated from different Indian potato cultivars (Kufri Sindhuri, Kufri Jyoti, Kufri Pukhraj, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Bahar and Kufri Chandermukhi) were evaluated for granule size, amylopectin structure, thermal and pasting properties. The changes in viscoelastic properties of cooked starch pastes during cooling and heating were also evaluated using a dynamic rheometer. Unit chains of amylopectin between DP 6 and 30 were analyzed by fluorophore-assisted capillary electrophoresis. Pearson correlation coefficients between different properties were also determined. Starches from all the cultivars showed peak DP 12–13. DP 6–7 content varied significantly among the starches studied; K. Chandermukhi showed the highest and K. Pukhraj showed the lowest. K. Chandermukhi starch showed significantly lower DP 14–30 content than starches from other potato cultivars. DP 14–30 content was in the order of K. Chipsona-1 > K. Jyoti > K. Sindhuri > K. Pukhraj > K. Bahar > K. Chipsona-2 > K. Chandermukhi. DP 6 was significantly and negatively correlated to peak gelatinization temperature (T_p) and conclusion temperature (T_c) ($r = -0.780$ and -0.824, respectively, $p \leqslant 0.05$). Pasting temperature, hot-paste viscosity and cold-paste viscosity showed significantly negative correlation with DP 6 ($r = -0.780$, -0.824 and -0.808, respectively, $p \leqslant 0.05$). However, pasting temperature, hot-paste viscosity and cold-paste viscosity showed positive correlation with DP 15–17. K. Pukhraj with the lowest amount of short-side-chain amylopectin fraction showed the highest moduli. K. Pukhraj starch with G' much greater than G'' indicates its predominantly more elastic than viscous character. Chipsona-2 and K. Chandermukhi starches with a higher amount of short-chain amylopectin fractions (DP 6–12) showed a greater change in moduli during cooling of cooked paste and had more viscous character than other starches with lower amounts of these fractions.

Keywords: Potato starch; Thermal; Rheology; Amylopectin structure; Pasting properties

1. Introduction

The physico-chemical, morphological and functional properties of starches separated from potato cultivars have been reported earlier in a number of studies (Kaur, Singh, Ezekiel, & Guraya, 2007; Kaur, Singh, & Sodhi, 2002; Kim, Wiesenborn, Orr, & Grant, 1995; Morrison et al., 2000; Singh & Singh, 2001; Singh, Singh, Kaur, Sodhi, & Gill, 2003; Singh N, Kaur, & Singh, 2004; Tester & Karkalas, 2002; Yusuph, Tester, Ansell, & Snape, 2003). Different properties of potato starches such as phosphorus content, granule size, pasting properties, etc. have been reported to be affected by environmental factors such as temperature during growth, harvest date and storage temperature (Kaur et al., 2007; Noda et al., 2004; Tester, Ansell, Snape, & Yusuph, 2005; Yusuph et al., 2003), genotypes and cultural practices (Barichello, Yada, & Coffin, 1991). Hase and Plate (1996) found that total starch and starch phosphorus contents, as well as granule size distributions of starch from different varieties of potatoes, showed large variation due to genotype and environment factors, while amylose contents of starch did not vary largely. Kaur et al. (2007) reported that temperature that

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prevails in a region during tuber growth affects granule size, pasting temperature and transition temperature of the starch. They reported that tubers grown in regions with lower temperature resulted in starches with higher granule size and lower pasting and transition temperatures than tubers grown in regions with higher temperature. Tester, Debon, Davies, and Gidley (1999) found that the amylose and phosphorus content of the starch varied to some extent while granule size tended to decrease with increase in growth temperature. Many studies on the characterization of starch from potatoes with different genotypes and sources have been carried out in order to identify starches or sources of starches having properties similar to chemically modified starches (Barichello et al., 1991; Kim et al., 1995; Yusuph et al., 2003). The physico-chemical and morphological characteristics of potato starches play a significant role during potato starch modifications (Kaur, Singh, & Singh 2002; Singh J et al., 2004; Singh N et al., 2004). Also, it has been suggested that native starches selected from suitable cultivars with unique properties may have the potential to replace chemically modified starches, for example, high phosphorus content, decreased pasting temperature, increased peak viscosity and freeze thaw stability (McComber, Osman, & Lohnes, 1988). Potato starches with higher phosphorus content are therefore highly desirable because a high natural degree of phosphorylation avoids or reduces expensive and environmentally unfriendly industrial chemical processes. In the present study we have reported the relationship of unit chains of amylopectin between DP 6 and 30 with thermal and viscoelastic properties of potato starches.

2. Materials and methods

2.1. Materials

The tubers *Solanum tuberosum* L. cv Kufri Sindhuri, Kufri Jyoti, Kufri Pukhraj, Kufri Chipsona-1, Kufri Chipsona-2, Kufri Bahar and Kufri Chandermukhi were procured from Central Potato Research Institute (CPRI), Shimla from the 2003 harvest.

2.2. Starch isolation

Starches were isolated from different potato cultivars as described earlier (Singh & Singh, 2001). Potatoes were washed, brushed and peeled. The eyes and all bruises were pitted. Immediately after peeling, the potatoes were cut into small pieces (4 cm^2) and dipped in distilled water containing a small amount of potassium metabisulfite (35 g/100 l). The juice was extracted from potato pieces using a laboratory-scale juicer. A small quantity of potassium metabisulfite (5 g/l) was added to the juice to avoid browning. The juice was filtered through muslin cloth. The residue left on the muslin cloth was washed with distilled water, until only small amounts of starch were passing the muslin cloth. Filtrate was collected in a glass beaker and residue left on the muslin cloth was discarded. The beaker containing filtrate was kept undisturbed 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 become transparent. The starch cake was collected and dried at a temperature of 40 °C in a hot-air cabinet drier.

2.3. Amylose content and amylopectin structure

The amylose content of starch was determined using the method of Williams, Kuzina, and Hlynka (1970). Unit chains of amylopectin between DP 6 and 30 were analyzed by fluorophore-assisted capillary electrophoresis as described earlier (Srichuwong, Sunarti, Mishima, Isono, & Hisamatsu, 2005). The analysis was done in duplicate.

2.4. Particle size analysis

Particle size analysis of starches was done using a Coulter small-volume module model LS230 laser light scattering particle size analyzer as described earlier (Kaur, Singh, Sandhu, & Guraya, 2003).

2.5. Thermal properties

Thermal properties of isolated starches were analyzed using a Setaram Differential Scanning Calorimeter (France). Starch (200 mg) was weighed in a hastelloy cell. Distilled water was added using a Hamilton microsyringe to achieve a starch–water suspension containing 70% water. Samples were hermetically sealed in a DSC cell and allowed to stand for 1 h at 25 °C in DSC followed by heating at a rate of 1 °C/min from 25 to 110 °C and cooling to 5 °C with the same rate. Distilled water was used as reference. Onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and heat of gelatinization (ΔH_{gel}) were calculated automatically. The gelatinization range (ΔT) was computed as $2(T_p - T_o)$.

2.6. Pasting properties

The pasting properties were determined using RVA-4 (Newport Scientific Pvt. Ltd., Australia) using different potato starches. A suspension of 3 g (14% moisture basis) starch in 25 g of accurately weighed distilled water underwent a controlled heating and cooling cycle under constant shear where it was held at 50 °C for 1 min, heated from 50 to 95 °C at 8 °C/min and held at 95 °C for 2.7 min, cooled to 50 °C at 8 °C/min and held at 50 °C for 2 min. Pasting parameters such as pasting temperature (P_{temp}), peak viscosity (PV); hot paste viscosity (HPV), viscosity at the end of a hold time at 95 °C; cold paste viscosity (CPV), viscosity at the end of hold time at 50 °C; and setback (CPV-HPV) were recorded.