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Pasting properties of blends of potato, rice and maize starches

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ABSTRACT

In many food applications, chemically modified starches outperform their native starch counterparts. Starch blends are interesting clean label alternatives with potential for the food industry. Here, potato starch was blended with regular rice, waxy rice, regular maize or waxy maize starch in different ratios (100:0, 75:25, 50:50, 25:75 and 0:100). To elucidate the factors determining pasting, different total starch concentrations were used and swelling power and carbohydrate leaching were determined. During pasting, the starches in the blends impacted each other. Peak viscosities of the blends were lower than expected, especially at lower total starch concentrations (<6.0%) due to reduced swelling in the blend. At higher starch concentrations (>6.0%), the relation between peak viscosity and the percentage of a given starch in a blend was rather linear. Under such conditions, viscosity development is determined by granule rigidity rather than by swelling power. Minimum and end viscosities of the blends were intermediate between those of the individual starches at lower total starch concentrations. In contrast, at higher concentrations, minimum and end viscosities were as high as or even higher than the readings for potato starch, especially for blends of potato starch with rice or maize starch. Probably, reduced swelling led to a more conserved granular integrity during cooling which, along with interactions between leached molecules, can contribute to viscosity development. These results indicate that pasting of starch blends does not only depend on the individual starches and the blend composition, but also on the total starch concentration.

1. Introduction

Starch is a main energy supplier in the human diet. In addition, it is used by the food industry in a broad range of products because of its gelling, thickening and food system stabilizing capacity. However, starches are often chemically modified to meet the high process and product requirements of the industry. Chemical modifications such as cross-linking and substitution can increase the resistance to shear, acid and high temperatures, reduce retrogradation and improve freeze–thaw stability. In view of the increasing demand for more natural food products, clean label ways to modify starch properties are of interest to the food industry. One way to modify starch properties in a natural way is by physical modification (*e.g.* heat treatment) (Singh, Kaur, & McCarthy, 2007). Besides physical modifications, blending different native starches is another way to obtain new starch properties. It may also offer an economic advantage when a more expensive starch can be partially replaced by a cheaper alternative without affecting product quality. Starch blends are already used in a number of products (*e.g.* extruded snacks) and more insight in interactions between starches is of interest for further product development.

When discussing starch blends, a distinction can be made between additive and non-additive effects. When starches in the blend influence each other and the properties of the blend cannot be predicted based on the properties of the individual starches, there is a non-additive effect. In contrast, an additive effect is observed when the outcome of the blend can be predicted from the properties of the individual starches (Puncha-arnon, Pathipanawat, Puttanlek, Rungsardthong, & Uttapap, 2008; Yao, Zhang, & Ding, 2003).

Pasting involves swelling of the granules, leaching of carbohydrates, formation of a three-dimensional network of leached molecules and interactions between granule remnants and the leached material (Atwell, Hood, Lineback, Varriano-Marston, & Zobel, 1988). It is determined by the starch botanical origin, its amylose content, amylopectin chain length distribution, swelling power, concentration and process conditions such as shearing and heating rates (Blazek & Copeland, 2008; Doublier, Llamas, & Lemeur, 1987; Gomand, Lamberts, Visser, & Delcour, 2010; Jane et al., 1999; Tester & Morrison, 1990; Vandeputte, Derycke, Geeroms, &

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Delcour, 2003). An important characteristic of starch is its close packing concentration (C^*). C^* is the concentration at which the swollen granules fully fill up the available space at a certain temperature. When the concentration of a starch suspension is below its C^*, the viscosity of the system is mainly determined by the volume fraction of the granules and thus their swelling power (SP). When it exceeds C^*, the viscosity is mainly determined by the rigidity of the granules (Eerlingen, Jacobs, Block, & Delcour, 1997; Steeneken, 1989).

When two different starches are pasted together, they influence each other in many blends. Peak viscosity is lower than expected for blends of regular and high amylose maize starches (Juhasz & Salgo, 2008), different regular rice starches (Hagenimana & Ding, 2005), [heat-moisture treated (HMT)] potato and (HMT) amaranth starches (Gunaratne & Corke, 2007), potato and wheat starches (Obanni & BeMiller, 1997), potato and maize starches (Obanni & BeMiller, 1997), potato and waxy maize starches (Lin, Kao, Tsai, & Chang, 2013; Park, Kim, Kim, & Lim, 2009), potato and rice starches (Sandhu, Kaur, & Mukesh, 2010), canna and rice starches (Puncha-arnon et al., 2008) and cassava and lima bean starches (Novelo-Cen & Betancur-Ancona, 2005). This may be due to a reduced swelling in the blends. Possibly, the presence of one starch inhibits swelling of the other due to competition for water (Lin et al., 2013; Park et al., 2009; Puncha-arnon et al., 2008; Zhang, Gu, Hong, Li, & Cheng, 2011). Microscopic observations of gels of blends of potato and waxy maize starches (Lin et al., 2013; Park et al., 2009), potato and rice starches (Lin et al., 2013), regular and waxy rice starches (Chen, Lai, & Lii, 2003) and cassava, yam and maize starches (Karam, Grossmann, Silva, Ferrero, & Zaritzky, 2005) indeed revealed reduced swelling of one starch in the blend. In contrast, an additive effect for peak viscosity has been observed for blends of waxy maize and high amylose maize (Juhasz & Salgo, 2008), wheat and sweet potato starches (Zhu & Corke, 2011), potato and maize starches (Zhang et al., 2011), canna and potato starches (Puncha-arnon et al., 2008) and potato and mung bean starches (Puncha-arnon et al., 2008).

Blends of regular and waxy rice starches (Hagenimana & Ding, 2005), wheat and sweet potato starches (Zhu & Corke, 2011), potato and (HMT) amaranth starches (Gunaratne & Corke, 2007), regular and waxy maize starches (Obanni & BeMiller, 1997), potato and waxy rice starches (Lin et al., 2013) and potato and waxy maize starches (Lin et al., 2013) display two pasting peaks. According to Hagenimana and Ding (2005) and Zhu and Corke (2011), this results from independent gelatinisation of both starches. The starch with the lowest gelatinisation temperature causes the first viscosity rise, the other starch takes over when the first starch starts to break down. However, according to Obanni and BeMiller (1997) and Gunaratne and Corke (2007), the double peak is caused by interactions between the starches.

Interactions between starches during the heating phase and differences in swelling behaviour also affect gelation during cooling of the gel. End viscosity of starch blends differ from the expected values in most blends and, depending on the combination, an increase or decrease in end viscosity is observed. Blends of waxy maize and high amylose maize starches (Juhasz & Salgo, 2008), regular and waxy rice starches (Hagenimana & Ding, 2005), potato and HMT amaranth starches (Gunaratne & Corke, 2007), potato and waxy maize starches (Lin et al., 2013; Park et al., 2009), potato and maize starches (Zhang et al., 2011), potato and waxy rice starches (Lin et al., 2013), wheat and sweet potato starches (Zhu & Corke, 2011), potato and canna starches (Puncha-arnon et al., 2008) and canna and mung bean starches (Puncha-arnon et al., 2008) show higher end viscosities than expected. This may be due to increased interactions between leached molecules and swollen granule remnants (Park et al., 2009; Puncha-arnon et al., 2008; Zhang et al., 2011). In contrast, a lower end viscosity than expected has been observed for blends of regular and waxy maize starches (Juhasz & Salgo, 2008; Obanni & BeMiller, 1997), regular and high amylose maize starches (Juhasz & Salgo, 2008), regular and waxy rice starches (Chen, Lai, & Lii, 2004), cassava and lima bean starches (Novelo-Cen & Betancur-Ancona, 2005), potato and rice starches (Sandhu et al., 2010), rice and canna starches (Puncha-arnon et al., 2008), HMT potato and (HMT) amaranth starches (Gunaratne & Corke, 2007). This could be explained by lower swelling power and carbohydrate leaching of the starches in the blends (Puncha-arnon et al., 2008).

It is clear that the observed effects highly depend on the individual starches and their properties. Here, the role of amylose in blends will be studied by blending both regular and waxy maize and rice starches with potato starch. In addition, we will study the role of starch concentration. To the best of our knowledge, previous research was done with only one total starch concentration. Investigation of the role of starch concentration together with determination of swelling power and carbohydrate leaching at the point when granules of 100% potato starch are maximally swollen, will generate new insights in the interactions between starches.

2. Materials and methods

2.1. Materials

Potato starch (PS), regular maize (MS) and waxy maize (WMS) starches were obtained from Cargill (Vilvoorde, Belgium). Regular rice (RS) and waxy rice (WRS) starches were from Beneo Remy (Wijgmaal, Belgium). For the blends, five different ratios (0–100, 25–75, 50–50, 75–25 and 100–0) were used.

2.2. Swelling power and carbohydrate leaching

SP of the individual starches was determined essentially as in Eerlingen et al. (1997). Starch suspensions (1.11% w/v for cereal starches and 0.25% w/v for potato starch) were heated at 75 °C or at 95 °C for 30 min with shaking every 5 min (low shear). The samples were allowed to cool for 5 min and centrifuged for 30 min at 4000 *g*. The supernatant was removed and the sediment was weighed. Carbohydrate leaching (CHL) was determined on the supernatant as in Dubois, Gilles, Hamilton, Rebers, and Smith (1956) and expressed as a percentage of total dry matter starch. SP and C^* were calculated with formulas (1) and (2).

$$\mathrm{SP} = \frac{\text{sediment weight} \times 100}{(\text{dry matter starch weight}) \times (100 - \%\mathrm{CHL})} \quad (1)$$

$$C^* = \frac{\text{dry matter starch weight} \times 100}{\text{sediment weight}} \quad (2)$$

2.3. Gelatinisation properties

Gelatinisation onset (T_o), peak (T_p) and conclusion (T_c) temperatures of individual starches were measured in triplicate using Differential Scanning Calorimetry (DSC) (Q1000, TA Instruments, New Castle, DE, USA) and TA Universal analysis software. Starch (3–5 mg) was accurately weighed into an aluminium pan and deionized water was added [excess water, 1:3 starch dry matter (dm):water]. Samples were heated from 0 to 120 °C at 4 °C/min and an empty pan was used as reference. Calibration was done with indium.