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Guar and xanthan gum differentially affect shear induced breakdown of native waxy maize starch

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ABSTRACT

Starches and non-starch hydrocolloids or gums are used very often as texturizers in the food industry. The aim of this work was to investigate the effects of guar gum and xanthan gum on the mild temperature pasting behavior of waxy maize starch. Waxy maize starch dispersions containing either guar, xanthan or no gum were pasted at temperatures (70 and 72.5 °C) close to the gelatinization temperature by means of the starch pasting cell mounted on the rheometer. Different shear conditions were imposed (no shear, 50 s^{-1} and 150 s^{-1}). Along with the pasting behavior, the particle size distribution of the swollen granules was derived by means of laser light scattering and the rheological behavior of the cooled pastes was determined to characterize the samples. Finally, confocal laser scanning microscopy was used to locate the fluorescently labeled gums in the swollen starch dispersions. Under the given conditions, both gums differently affected the starch during the heating steps. While xanthan gum lowered the shear induced breakdown of the granules, guar gum did not show this specific property. Consequently, guar gum primarily modified the rheological properties of the pastes by its presence in the continuous phase, whereas xanthan gum also induced indirect effects by better preserving the granular structure.

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1. Introduction

Starch is frequently used in the food industry as a thickener or gelling agent. Very often, non-starch hydrocolloids or gums are added to improve the final properties and stability of starch-containing foodstuffs (Arocas, Sanz, & Fisman, 2009; Dolz, Hernandez, & Delegido, 2006; Heyman, Depypere, Delbaere, & Dewettinck, 2010; Sikora, Badrie, Deisingh, & Kowalski, 2008). Guar and xanthan are two of the most commonly used gums in combination with starches. Xanthan gum is an extracellular polysaccharide, produced by fermentation of *Xanthomonas campestris* and consists of 1,4-linked β-D-glucose residues having a trisaccharide side chain attached to O-3 of alternate D-glucosyl residues. The side chains are (3→1)-α-linked D-mannopyranose, (4→1)-β-D-mannopyranose and (2→1)-β-D-glucuronic acid (Born, Langendorff, & Boulenguer, 2005). Guar gum is derived from the ground endosperm of guar seeds (*Cyamopsis tetragonoloba*). This non-ionic polysaccharide has a main chain of (1→4)-linked β-D-mannopyranosyl units with single α-D-galactopyranosyl units attached to the O-6 position (Casas, Mohedano, & Garcia-Ochoa, 2000; Mudgil, Barak, & Khatkar, 2012).

The specific effects of gums on the pasting and rheological properties of starches have been extensively studied. They appear to strongly depend on both gum and starch type as well as the applied concentrations and preparation conditions (BeMiller, 2011). The origin of their rheological synergies in particular has received much attention. Associations between starch and hydrocolloid molecules (Christianson, Hodge, Osborne, & Detroy, 1981; Freitas, Gorin, Neves, & Sierakowski, 2003; Funami et al., 2005b; Shi & BeMiller, 2002) as well as their mutual exclusion (Achayuthakan & Suphantharika, 2008; Alloncle & Doublier, 1991; Alloncle, Lefebvre, Llamas, & Doublier, 1989; Biliaderis, Arvanitoyannis, Izydorczyk, & Prokopowich, 1997; Conde-Petit, Pfirter, & Escher,

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1997; Mandala, Michon, & Launay, 2004) has been proposed to explain the observed rheological phenomena.

In addition to their direct effects in the bulk phase, gums could also indirectly govern the rheological behavior of starch pastes by modifying the properties of the granules. In this regard, the suggestion is made that they can compensate the shortcomings of native starches hence reducing the need for chemically modified starches (BeMiller, 2011; Brennan, Tan, Kuri, & Tudorica, 2004). When heated together, gums can influence the swelling and degradation behavior of the starch. In general, inhibition of the granule swelling due to the hydrocolloid is observed (Achayuthakan and Suphantharika, 2008; Biliaderis et al., 1997; Funami et al., 2005a; Kruger, Ferrero, & Zaritzky, 2003; Song, Kwon, Choi, Kim, & Shin, 2006; Temsiripong, Pongsawatmanit, Ikeda, & Nishinari, 2005; Tester & Sommerville, 2003), with some rare observations of increased granule swelling (Achayuthakan, Suphantharika, & Rao, 2006; Mandala & Bayas, 2004). Kaur, Singh, Singh, and McCarthy (2008) found that the expansion of starches with a high swelling capacity was reduced whereas the effect on low swelling starches was limited. Both kinetic and chemical effects could be held responsible for the differing effects. Kruger et al. (2003) suggested that in the presence of gums, granule swelling was inhibited because of the lower heating rates and the reduced mobility of the water molecules. It was also demonstrated that gums can inhibit the leaching of starch polymers (primarily amylose) during pasting (Biliaderis et al., 1997; Chaisawang & Suphantharika, 2006; Hongsprabhas, Israkarn, & Rattanawattanaprakit, 2007; Shi & BeMiller, 2002). In this manner swelling is restricted, resulting in more rigid granules which break up less easily. Some gums are expected to induce a smooth flow of starch dispersions, hereby preventing the abrasion of starch granules (Funami et al., 2008; Viturawong, Achayuthakan, & Suphantharika, 2008). On the contrary, the increased breakdown as derived from rapid visco-analyzer or Brabender pasting curves convinced other authors that instead of preserving their structure, gums stimulate rupture of the granules (Chaisawang & Suphantharika, 2006; Christianson et al., 1981; Mandala & Bayas, 2004). It was proposed that due to the higher medium viscosity, the shear forces exerted on the granules are increased, which results in more breakdown.

The aim of this experimental setup was to gain a better insight in the effects of two commercially important gums, guar and xanthan, on the behavior of waxy maize starch during pasting. By using waxy starches, which consist almost entirely of amylopectin, effects of gums on amylose leaching and amylose gelation can be excluded. However, in its native form this type of starch is vulnerable to both thermal and shear-induced breakdown (Schirmer, Höchstötter, Jekle, Arendt, & Becker, 2013), which restricts its use in industrial applications. Therefore it is interesting to search for ways to better preserve their structure, for example by the addition of gums or by the use of adjusted processing conditions. In most experimental setups, the intense heating of the starches results in microstructurally complex systems of granule remnants and granule ghosts within a macromolecular solution of amylopectin and gums, because the majority of the granules is broken down (Hermansson & Svegmark, 1996; Tsai, Li, & Lii, 1997). Therefore, it is difficult to draw conclusions regarding the effect of gums on the granule swelling and degradation. As demonstrated in our recently published research (Heyman, Depypere, Van der Meeren, & Dewettinck, 2013), the processing of waxy starches at temperatures close to the gelatinization range, helps to limit their breakdown. Furthermore it was shown that at these mild temperatures, the presence of xanthan gum induced larger granule diameters in the final paste. However, the underlying mechanisms were unclear. The comparison of guar and xanthan gum should clarify if these phenomena are caused by a specific feature of xanthan gum or if another effective food thickener can induce similar effects. Furthermore, in order to elucidate the underlying mechanisms, the pastes were prepared under varying conditions: heating (70 or 72.5 °C) was performed under static as well as under shearing conditions.

Due to its anionic nature, xanthan gum is sensitive to variations in salt content, which in turn affects its functionality when combined with starches (Samutsri & Suphantharika, 2012; Viturawong et al., 2008). Throughout the manuscript, a salt concentration of 0.01 M will be maintained, however, the effect of varying salt concentrations will be briefly touched as well.

2. Materials and methods

2.1. Materials

Xanthan gum (Satiaxane CX911, pyruvic acid content >1.5%) and guar gum (Viscogum MP41230) were acquired from Cargill Texturizing Solutions (Ghent, Belgium). Native waxy maize starch (Merizet 300) was provided by Tate & Lyle Benelux.

2.2. Preparation of gum solutions

Xanthan gum powder was dispersed in deionized water, whilst continuously stirring with a magnetic stirrer. The NaCl concentration was adjusted to 0.01 M for all the experiments, except for one part of the setup, where no salt was added to the xanthan solutions (this is also clearly mentioned in the text). The premix (2.5 L) was put in an Ekato Unimix LM3 laboratory mixer (EKATO Rühr- und Mischtechnik GmbH, Schopfheim, Germany), a mixing apparatus equipped with a temperature control system, paravisc agitator with revolving blades and a colloid mill homogenizer. To fully dissolve the xanthan gum, the premix was homogenized at room temperature for 15 min at 5000 rpm and stirred at an agitation speed of 150 rpm. During homogenization, the unimix system was placed under vacuum to limit air inclusion. The resulting solution of xanthan (0.8% w/v) was heated to 85 °C by means of the unimix system (10 min, stirred at 150 rpm). Guar gum stock solutions (1 L) were prepared by dissolving the gum powder (0.8% w/v) in deionized water, followed by heating to 70 °C and continued magnetic stirring at room temperature for 4 h. The NaCl content was brought to 0.01 M. Both hydrocolloid stock solutions were allowed to rest overnight (at 5 °C) before use.

2.3. Pasting experiments

The starch powder was suspended either in a 0.01 M NaCl solution (for preparation of the gum-free pastes), or in a mixture of the NaCl solution and gum stock solutions. In this manner, starch slurries were obtained with three different gum concentrations in the continuous phase: 0%, 0.2% and 0.4%, all of which had a salt concentration of 0.01 M NaCl. The resulting starch:solvent ratio in all cases was kept constant at 5:100 (w:w).

The dispersions were transferred to the starch pasting cell mounted on a controlled stress rheometer AR2000 (TA Instruments, New Castle, USA). This rheometer geometry consists of a jacket, a removable cup and an impeller. A gap of 5500 μm between rotor and the bottom of the cup is used. Since the impeller produces an ill-defined flow, analytical conversion factors to calculate shear rate or shear stress are not available. Conversion factors for shear rate (4.500) and shear stress (48,600 m^{-3}) were determined by the manufacturer by performing a calibration with both Newtonian and non-Newtonian oil (De Graef, van Puyvelde, Goderis, & Dewettinck, 2009). For the sake of simplicity, the word 'shear rate' is used although the actual shear rates occurring in the sample will vary throughout the sample volume.

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