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Effect of heat-moisture treatment with maltitol on physicochemical properties of wheat starch

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ABSTRACT

Effect of heat-moisture treatment (HMT) with maltitol on physicochemical properties of wheat starch was investigated. Compared with the mixture of maltitol and wheat starch (MAWS), peak viscosity, trough viscosity, final viscosity, breakdown and setback of MAWS modified by heat-moisture treatment (HMT-MAWS) was decreased by 119.29, 63.37, 84.50, 55.92, 21.12 RVU, respectively. The viscosities of HMT-MAWS were affected more remarkably than that of the mixture of maltitol and heat-moisture treatment modified wheat starch (MA-HMTWS). Gelatinization temperature (To, Tp, Tc) of HMT-MAWS increased significantly than that of MAWS. Scanning electron microscope showed that a layer of membrane-like substance adhered to the smooth surface of HMT-MAWS, but that of MAWS became rough with a lot of small particles. After gelatinization and freeze drying, the gel structure of HMT-MAWS was tighter than that of MAWS. According to X-ray diffraction pattern, the area of amorphous region of HMT-MAWS was higher than that of MAWS.

1. Introduction

Starch is the main polysaccharide in plant-origin food products. It is commonly used as thickener, colloidal stabilizer, gelling, bulking and water preserving agent. The granule swelling, gelatinization, pasting and the subsequent gel properties of starch play important roles in the food manufacturing industry. With the use of starch in food industry becoming increasingly broader and more extensive, native starch does not always possess the physicochemical properties appropriate for certain types of processing. Starch is often modified by physical, chemical, and enzymatic processes to promote specific functional properties. Heat-moisture treatment (HMT) is one of the more important physical methods by using simple and environmentally safe processes, with low cost and without by-products of chemical reagents (Adebowale, Olu-Owolabi, Olayinka, & Lawal, 2005; Sun, Wang, Xiong, & Zhao, 2013; Zavareze & Dias, 2011). HMT involves treatment of starch granules at low moisture levels (<35 g/100 g) within a certain time period (15 min–16 h) and at a specific range of temperature (84–120 °C) above the glass transition temperature but below the gelatinization temperature (Gunaratne & Hoover, 2002; Hoover & Vasanthan, 1994; Takaya, Sano, & Nishinari, 2000).

Additives such as sugar are commonly used in starch-based foods in order to optimize the processing operation and enhance food quality by influencing the gelatinization and retrogradation of starch. However, food high in sugar and calories can lead to diseases such as obesity and diabetes. In recent times, people pay more attention to healthy eating habits and low-calorie diets. The possibility of using sugar alcohol instead of sucrose as a sweetener has attracted more and more researchers' attention (Kommineni, Amamcharla, & Metzger, 2012; Lin, Lee, Mau, Lin, & Chiou, 2010). Maltitol, a sugar alcohol used to replace table sugar as a sugar substitute, has fewer calories, does not promote tooth decay and has a lesser effect on blood glucose. The chemical property of maltitol is known as 4-O-α-glucopyranosyl-D-sorbitol.

Some researchers have already studied the effects of sugar alcohol on the physicochemical properties of starch. Lourdin, Bizot, Colonna, and Coignard (1997) indicated that sorbitol was one of the natural plasticizers for starch vitreous behavior whereas other researches held that sorbitol, depending on its concentration in the starch system, behaved as an antiplasticizer (Gaudin, Lourdin, Forssell, & Colonna, 2000; Mantzari, Raphaelides, & Exarhopoulos, 2010). The freezing behavior of corn starch gels with xylitol, mannitol, and sorbitol exhibited higher freezing levels than that of corresponding sugars (Baek, Yoo, & Lim, 2004; Kim,

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Yoo, Cornillon, & Lim, 2004). However, few studies have reported the effect of maltitol on the physicochemical properties of wheat starch (WS), especially with HMT.

The objective of this research is to study the effect of HMT with maltitol on pasting properties, thermal properties, morphological and structural properties of WS. This study will give new ways to application of sugar-free starchy products.

2. Materials and methods

2.1. Materials

Wheat starch (WS) was supplied by Tianjin Tingfung Starch Development Co., Ltd (Tianjin, China). Maltitol was purchased from Futaste Co., Ltd (Shandong, China). All other reagents used were of analytical grades.

2.2. Methods

2.2.1. Samples preparation

Maltitol was mixed with WS (MAWS) at a solid weight ratio of 0.5:1 based on starch (dry weight), and then modified by HMT (HMT-MAWS) according to Hoover & Vasanthan, 1994. The content of moisture of samples was adjusted to 20 g/100 g by adding the appropriate amounts of distilled water into the containers. The containers were hermetically sealed and equilibrated at ambient temperature for 24 h. Resulting samples were then placed in an electric oven at 100 °C for 12 h, dried at 40 °C, ground and sieved (0.15 mm). WS modified by HMT (HMT-WS) was mixed with maltitol at a solid weight ratio of 0.5:1 based on starch (dry weight), the final sample maltitol-HMTWS (MA-HMTWS) was then obtained.

2.2.2. Pasting properties

Pasting properties of samples were determined by using RVA-4 (Newport Scientific Pvt. Ltd., Warriewood, Australia) according to the methods (Singh, Isono, Srichuwong, Noda, & Nishinari, 2008). A suspension of 3 g (12 g/100 g moisture basis) starch in 25 g of accurately weighed distilled water underwent a controlled heating and cooling cycle under constant shear. The slurry was then manually homogenized by using a plastic paddle to avoid lump formation before the RVA run. The rotating speed was maintained at 160 rpm along the process. Parameters including peak viscosity (PV), viscosity at the end of hold time at 95 °C or trough viscosity (TV), final viscosity (FV) at the end of cooling, breakdown (BD = PV − TV), setback (SB = FV − TV) and pasting temperature were recorded.

2.2.3. Thermal properties

Thermal properties of samples were assessed by a Pyris-1 differential scanning calorimeter (DSC) (Perkin–Elmer Co., Norwalk, CT, USA). The instrument was calibrated with indium and an empty pan was used as reference. Samples were hermetically sealed and equilibrated at ambient temperature for 24 h. Sample pan was heated from 25 °C to 120 °C at 10 °C/min. The onset (To), peak (Tp) and conclusion (Tc) gelatinization temperature as well as enthalpy (ΔH) were computed.

2.2.4. Scanning electron microscopy (SEM)

The surface topography of samples was observed with scanning electron microscopy (SEM) by using the method of Kim et al. (2008). WS, HTM-WS, MAWS and HTM-MAWS were cooked in boiling water for 20 min to prepare the gel samples, and then put into an ultralow temperature freezer and freeze dried for 48 h. Freeze-drying was carried out in the vacuum chamber where the chamber pressure was set to 0.13 Pa at room temperature (21 °C). The freeze-dried samples and uncooked granule samples were finely milled and then placed under vacuum on a double-sided Scotch tape, mounted on an aluminum specimen holder and coated with a thin film of gold. Samples were observed under a Jeol scanning electron microscope (JSM 840, Jeol, Tokyo, Japan).

2.2.5. X-ray diffraction

X-ray diffractograms of samples were obtained with an X-ray diffractometer (XRD-6000, Shimadzu, Tokyo, Japan). The scanning region of the diffraction ranged from 5 to 60° with a target voltage of 45 KV, current of 40 mA and scan speed of 1°/min.

2.2.6. Statistical analysis

All experiments were conducted at least three times, for which mean values and standard deviations were determined. Additionally, experimental data were analyzed by using Analysis of Variance (ANOVA), and expressed as mean values ± standard deviations. Differences were considered at significant level of 95% ($p < 0.05$). Pearson's correlation coefficients among other parameters were calculated by using SPSS 17.0 software.

3. Results and discussion

3.1. Pasting properties

RVA profiles of WS, HMT-WS, MAWS, HMT-MAWS and MA-HMTWS are presented in Fig. 1 and the corresponding pasting parameters are summarized in Table 1. The pasting temperature and setback of HMT-WS increased compared with that of the native WS. However, its peak viscosity, trough viscosity and breakdown decreased. In previous works, HMT-modified starches displayed an increased pasting temperature and a decreased pasting viscosity, regardless of origin (Hoover & Vasanthan, 1994; Stute, 1992; Varatharajan, Hoover, Liu, & Seetharaman, 2010; Watcharatewinkul, Puttanlek, Rungsardthong, & Uttapap, 2009), these findings were consistent with our results. The pasting temperature and breakdown of MAWS slightly decreased, but the peak viscosity, through viscosity, final viscosity and setback increased significantly. The addition of maltitol formed more hydrogen bonds with starch and inhibited the movement of starch chains which strengthened system dynamics, so the viscosity of starch paste increased. Previous researches showed that when the concentration of sorbitol was low (<60 g/100 g), the addition of sorbitol reinforced association among the starch chain, polyol and water

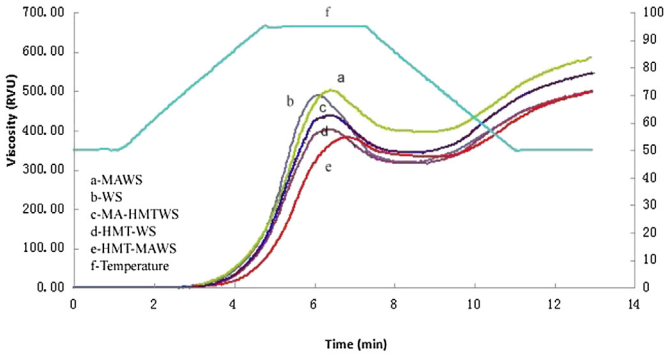

Fig. 1. Pasting properties of WS in the presence of maltitol with heat-moisture treatment. WS: Wheat starch; HMT-WS: Wheat starch modified by heat-moisture; MAWS: Mixture of maltitol and wheat starch; HMT-MAWS: Mixture of maltitol and wheat starch modified by heat-moisture; MA-HMTWS: Mixture of maltitol and heat-moisture treatment modified wheat starch.