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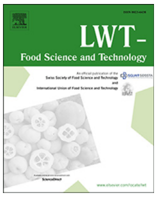

Effects of single and dual heat-moisture treatment combined with sodium alginate on the physicochemical properties of normal cornstarch

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A B S T R A C T

Modified starch is considered to be an important ingredient in the application of food industry. The present study investigates the physicochemical properties of normal cornstarch (NCS) treated with a single heat-moisture treatment (SHMT) or a dual heat-moisture treatment (DHMT) with an interval storage temperature of 25 °C (DHMT25), 4 °C (DHMT4) and −20 °C (DHMT-20) in the presence of sodium alginate (AG). The results showed that both SHMT and DHMT combined with AG increased the pasting temperature (PT), gelatinization conclusion temperature (T_c), gelatinization temperature range (T_c–T_o), and gel hardness of NCS, but they decreased the pasting viscosities, gelatinization onset temperature (T_o), gelatinization enthalpy (ΔH), and relative crystallinity (RC) of NCS. Neither SHMT nor DHMT combined with AG addition changed the crystalline type of NCS. Sodium alginate–normal cornstarch (AG-NCS) mixtures after SHMT showed the highest PT value and gel hardness, and they showed the lowest breakdown (BD) and setback (SB) values, indicating that AG-starch mixtures with SHMT had superior mechanical and thermal stability. AG-NCS after DHMT-20 showed the highest T_c and T_c–T_o values as well as the lowest ΔH and RC values, suggesting that the hydrothermal treatment had an effect on the structure changes of starch molecules. Above all, both SHMT and DHMT had effects on the properties of AG-NCS.

1. Introduction

Sodium alginate (AG) is a kind of hydrophilic colloid. Commercially available alginates currently come from algae, owing to its low cost, stable properties, unique pH sensitivity and biocompatibility. Alginates are usually used as food thickeners, emulsifiers, stabilizers, and controlled release agents of drugs (Siddhesh & Kevin, 2012). The formulation of starch-based products often involves the addition of hydrocolloids, which could be used to improve stability (avoiding syneresis) or to obtain specific textural characteristics (Krüger, Ferrero, & Zaritzky, 2003). Hydrocolloids can reduce the adverse effects of starch retrogradation during frozen storage (Ferrero, Martino, & Zaritzky, 1996). Biliaderis and Prokopowich (1994) pointed out that hydrocolloids exhibited beneficial effects on starch gelatinization and retrogradation (retarding or inhibiting starch retrogradation). Zhao, Chen, Wang, and Li (2016) studied the effect of AG and its guluronic acid/mannuronic acid ratio on the physicochemical properties of high-amylose cornstarch, which showed that AG with a low guluronic acid/mannuronic acid ratio can retard the short-term retrogradation of high-amylose cornstarch. Hydrophilic colloids together with starch in an appropriate ratio can also improve the texture, increase the moisture retention and modify the characteristics of the end food products (Song, Kwon, Choi, Kim, & Shin, 2006). Pongsawatmanit, Temsiripong, Ikeda, and Nishinari (2006) postulated that starch-hydrocolloid mixtures are good food thickeners and gelling agents. In addition, some scientists explained the function of hydrocolloids in mixed starch-gum dispersions which may be due to the interactions between hydroxyl groups in hydrocolloids and starch (Alloncle & Doublier, 1991; Funami et al., 2005; Sudhakar et al., 1996).

The use of starch in its native form is limited due to its undesirable defects, such as its poor solubility, low heat and shear resistance, uncontrolled paste consistency, high tendency toward

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retrogradation and gelling (BeMiller, 1997; Lawal, 2009). The modification of starch is widely used to improve and enhance its inherent properties for solving these problems. Physical modification is a highly safe method in starch modification (Klein, Pinto, & Vanier, 2013). Heat-moisture treatment (HMT) is a method of physical modification and treats starch granules at a moisture level lower than 35% (w/w) and at a temperature of 84–120 °C for 15 min–16 h (Khunae, Tran, & Sirivongpaisal, 2007). Many studies showed the effect of SHMT (a single HMT) or DHMT (HMT combined with annealing or a second HMT after storage at a certain temperature) on the physicochemical properties of starch alone. SHMT or DHMT exhibited influence on the molecular structures and physicochemical properties of rice, cassava, pinhao, and corn starches (Klein et al., 2013; Chung, Hoover, & Liu, 2009; Chung, Liu, & Hoover, 2010). Yadav, Guleria, and Yadav (2013) studied the effect of DHMT (SHMT combined with annealing treatment) conditions (such as DHMT temperature, moisture, and time) on the physicochemical properties of water chestnut starch. Shang, Chen, Wang, and Li (2016) studied the effect of SHMT and DHMT on the physicochemical properties of NCS. However, researchers have rarely reported the effects of SHMT and DHMT on the properties of starch-hydrocolloid.

Many researchers made modifications of starch-hydrocolloid mixtures with heat treatment to enhance their properties. Chandanasree, Gul, and Riar (2016) studied the effects of hydrocolloids and dry heat modification on the physicochemical, thermal, pasting, and morphological characteristics of cassava starch. The result indicated that the modified starch can be used for flavor encapsulation or the improvement of texture upon cooking with lower solubility and swelling power. Similar results were shown in earlier works in the literature (Gul, Riar, Bala, & Sibian, 2014; Lim, Han, BeMiller, & Lim, 2006; Lim, Han, Lim, & BeMiller, 2002; Pramodrao & Riar, 2014; Sun, Si, Xiong, & Chu, 2013; Sun, Xu, & Liu, 2014).

The authors Zhao et al. (2016) and Shang et al. (2016) previously studied the effects of AG, SHMT, and DHMT on the properties of cornstarch. According to the previous research studies, we found that both AG and HMT could improve the characteristics of cornstarch. Thus, the aim of this study was to investigate the effects of SHMT and DHMT at different interval temperatures (25 °C, 4 °C, −20 °C) on the pasting properties, gelatinization properties, gel hardness properties, and crystalline structure of AG-NCS mixtures. The effects of SHMT and DHMT combined with AG addition on the physicochemical properties of NCS would be explained better from this result.

2. Materials and methods

Normal cornstarch (NCS, amylose content of 26.2%) was purchased from Bingzhou Jinhui Corn Co. Ltd., Shandong, China. AG (the ratio of mannuronic acid to guluronic acid is about 1.17) was gifted by Qingdao Mingyue Haizao Ltd., Shandong, China. All other reagents used were analytical grade.

2.1. Heat-moisture treatment of AG-NCS mixtures

Preparation of AG-NCS mixtures: The preparation of an AG-NCS mixture was performed according to the method of Chen, Wang, Leng, Zhao, and Zhao (2014), with a slight modification. AG was first dispersed in distilled water, with magnetic stirring for 30 min. NCS was then poured into the AG solutions and stirred vigorously to avoid the formation of lumps. The mixture was dried at 40 °C in an oven until the water content was not higher than 10% and was then ground, sieved with 100 meshes, and ready to be used. The mixture without HMT is called AG-NCS-U.

HMT of AG-NCS mixtures: The AG-NCS mixture was adjusted to 25% moisture and was equilibrated at 25 °C for 24 h. For SHMT, the samples were heated at 120 °C for 6 h in an oven (AG-NCS-SHMT). For DHMT, the samples were heated at 120 °C in an oven for 6 h, and then remained in a covered container for 12 h at 25 °C, 4 °C, −20 °C, respectively. Then, the above samples were heated at 120 °C in an oven for 1 h again (AG-NCS-DHMT25, AG-NCS-DHMT4, AG-NCS-DHMT-20). After being dried at 40 °C in an oven, the treated samples were then ground, sieved with 100 meshes, and ready to be used. The moisture levels of AG-NCS-SHMT, AG-NCS-DHMT25, AG-NCS-DHMT4 and AG-NCS-DHMT-20 were 9.15%, 9.21%, 9.09%, and 9.53%, respectively.

2.2. Pasting properties

According to the method of Chen et al. (2014), a RVA-4D rapid viscometer analysier (Newport Scientific, Australia) and the STD1 procedure were used to measure the pasting properties of the samples. A 3-g sample (14 g/100 g wet basis) was weighed and dispersed in the distilled water to attain a total of 28 g. The pasting parameters were recorded. All tests were replicated five times.

2.3. Gel hardness

A TA-XT·Plus texture analyzer (Stable Micro Systems Ltd., Surrey, England) and a probe of P/0.5 (a type of cylinder probe with a 0.5-inch diameter) were used to measure the gel hardness. A 10% (w/w) of sample dispersion was pasted and kept at 95 °C for 10 min in an aluminium canister with a diameter of 4 cm and a height of 6 cm. The pasted sample was then cooled to room temperature in 5 min using an ice-water bath, and stored at 4 °C for 24 h in the canister sealed with parafilm. After being restored to room temperature, the gel sample was punctured at a test speed of 0.5 mm/s to 90% of the original height. The peak force was recorded as the gel hardness value (Chen et al., 2014). All tests were repeated five times.

2.4. Thermal properties

A DSC-1 differential scanning calorimeter (Mettler-Toledo International Inc., Switzerland) was used to determine the thermal properties of samples after calibration with indium in the nitrogen flow. The measurement was performed according to the method of Zhao et al. (2016). A 3-mg sample and 9-mg of water (sample-water ratio of 1:3, g/g) were weighed directly into the aluminum pans, and then hermetically sealed and equilibrated for 12 h. The sample was heated at a rate of 10 °C/min from 30 to 100 °C. The values of the gelatinization onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c), gelatinization temperature range (T_c–T_o), and gelatinization enthalpy (ΔH) were recorded and calculated. All tests were repeated three times.

2.5. X-ray diffraction

A D8-ADVANCE X-ray diffractometer (Bruker AXS, Inc., Germany) and copper-cobalt radiation were used to analyze the crystal structures of the samples with a target voltage of 40 kV and a current of 40 mA. Before analysis, the samples were equilibrated at room temperature for 24 h in a saturated relative humidity chamber. The scanning region of the diffraction ranged from 4 to 45° at a scan speed of 0.1°/s. The relative crystallinity (RC) of the mixtures was calculated as the ratio of the crystalline area to the total area of the crystalline and amorphous areas (Rabek, 1980).