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A comparative study of sodium dodecyl sulfate and freezing/thawing treatment on wheat starch: The role of water absorption

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ABSTRACT

The effect of freezing on functionality of native and sodium dodecyl sulfate (SDS)-treated wheat starches was investigated, with the aim of understanding the role of water absorption during freezing process. SDS is one of most efficient detergents to remove non-starch components (such as proteins and lipids) for starches but does not cause any apparent damage on granular structure. Slow swelling could be converted to rapid swelling by SDS washing, indicating higher water absorption. Freezing process induced slight roughness on starch granules but the non-starch components content was little affected. Combined SDS + freezing treatment significantly decreased both amylose and proteins non-starch components contents, which was accompanied with high gelatinization temperatures, melting enthalpy, and pasting viscosities. A smaller bread specific volume was obtained from SDS + freezing-treated starches while the crumb firmness significantly increased ($p < 0.05$). SDS mainly extracted the surface components from starch granules, leading to high water absorption and making granules sensitive to the freezing treatment.

1. Introduction

Low dough quality has been found after freezing/thawing cycles and long term frozen stage (Ribotta, León, & Añón, 2001). Numerous previous studies demonstrated that gluten network was damaged by ice-crystallization and re-crystallization during low temperature storage reports (Yadav, Patki, Sharma, & Bawa, 2009), whereas little information studied the counterparts of starch. Some of the recent studies investigated the effects of freezing on physicochemical properties of starch (Szymońska & Krok, 2003; Szymonska, Krok, & Tomasik, 2000; Tao, Wang, et al., 2015; Tao, Yan, et al., 2015; Tao, Wang, Ali, et al., 2016; Tao, Wang, Wu, et al., 2016). During the freezing process, water inside the starch granule expanded channels in the granule envelope. Compression of the starch granule by water matrix formed on freezing treatment caused leaching of the material (Szymonska et al., 2000; Tao, Wang, et al., 2015; Tao, Yan, et al., 2015). The surface leaching material resulted in some structure changes and accelerated retrogradation of starch or starchy foods (Meziani et al., 2011). It was further reported that small starch granules were more sensitive to the freezing treatment than large granules (Tao, Wang, Ali, et al., 2016; Tao, Wang, Wu et al., 2016), due to the fact that small starch granules have higher surface area and a higher affinity for water. It seemed that water absorption was correlated with deteriorated degree of starch granules induced by freezing.

Water absorption was as a function of starch participating in the breadmaking process (Añón et al., 2004). For this reason, it was recommended for breadmaking from frozen dough that the flour used did not have more than 7% damaged starch (Marston, 1978), since excessively high levels of damaged starch increased the water absorption capacity of flour, creating problems during dough handling and fermentation (Pomeranz, 1971). The dough with a high level of damaged starch became more viscous and resistant to deformations as well as less elastic and extensible (Barrera, León, & Ribotta, 2015). Bread loaf made of such dough is characterized with a sticky crumb and an opening of the crumb structure (Barrera, Pérez, Ribotta, & León, 2006). Therefore, water absorption was important for starch during baking and contributed to bread quality. Although more understanding on the factors affecting the formation of big ice crystals during the freezing process (Yadav

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et al., 2009), the effect of water absorption on starch sensitivity to freezing treatment was still limited.

Evidence showed that sodium dodecyl sulfate (SDS) could influence water absorption of starch by partial defatting or partial protein removal (Chan, Bhat, & Karim, 2010). The reaction occurred through enhancing the accessibility of water to the granule surface and interior of the granule (Debet & Gidley, 2006). Therefore, in the present study, functional properties of starches after freezing, SDS and combination of both treatments were evaluated to determine the water absorption functionality in frozen doughs. Regarding the quality of breads, specific volume and texture of breadcrumb were analyzed using a reconstituted dough with starch and gluten (Delcour et al., 2000). The addition of native wheat starches were substituted by freezing-treated starches, SDS-treated starches, and SDS + freezing starches to investigate the functional baking and basic biochemical examinations of wheat starch.

2. Materials and methods

2.1. Materials

Wheat starch was provided by Puluoxing Starch Co., Ltd. (Hangzhou, China). Commercial wheat gluten [protein content ($N \times 6.25$) 62.1%] was obtained from Weijing Co., Ltd. (Shanghai, China). Yeast, sugar, and salt were purchased from a local market in Wuxi, China. All other chemicals and reagents were obtained from Sinopharm Chemical Reagent Co., Ltd. (Suzhou, China) and were of analytical grade unless otherwise stated.

2.2. Sodium dodecyl sulfate and freezing/thawing treatment

For removing minor components of starch, wheat starch granules (100 g) and 2000 mL of 1% sodium dodecyl sulfate (SDS) solution were mixed in a 5000 mL conical glass flask. This suspension was stirred for 30 min and centrifuged at 3000×*g* for 10 min (Seguchi & Yamada, 1989). The pellet was washed five times, resuspended with distilled water, centrifuged and dried in the oven at 37 °C for 48 h. For treatment involving freezing, the prepared wheat starch samples were dispersed in deionized water in a ratio of 1:1.5 (w/w). Then they were subjected to 3 cycles of freezing/thawing process and centrifuged at 2200*g* for 20 min (Tao, Wang, et al., 2015; Tao, Yan, et al., 2015). Combination of SDS and freezing/thawing treatments was done by first treating the starch sample with SDS solvent as previously described. After the pellet was washed five times, it was subsequently subjected to freezing treatment for 3 cycles. One sample from each treatment for each type of starch was prepared and kept until further analysis.

2.3. Chemical composition contents

The apparent amylose content was determined by the iodine binding colorimetric method (Wang et al., 2014). The protein content of centrifuged pellets was measured by the kjeldahl method (Kjeldahl, 1883). Lipid content of starches was determined gravimetrically after extraction with ether at 70 °C for 8 h.

2.4. Granule morphology

Images of native and treated starch granules were performed using a Hitachi S-4800 (Hitachi, Japan) at an acceleration voltage of 5 kV with ×1000 and ×3000 magnification, respectively. The freeze-dried starch samples were placed on aluminum specimen stubs with double-sided adhesive tape and coated with gold for observation.

2.5. Differential scanning calorimetry (DSC)

Thermal properties of starch samples were analyzed by a differential scanning calorimetry 7000 instrument (Seiko Instruments Inc., Chiba, Japan) according to the method of Tao, Wang, et al. (2015) and Tao, Yan, et al. (2015). A total weight of 3.0 mg samples (dry basis) and distilled water (6 μL) were placed in pre-weighed aluminum sample pans. The pans were sealed hermetically to prevent moisture loss and kept overnight. For all DSC runs, a sealed empty aluminum pan was used as a reference. All pans were allowed to equilibrate at 4 °C for 24 h and then heated from 30 °C to 90 °C at a constant rate of 10 °C/min using nitrogen gas (80 mL/min). The gelatinization onset, peak temperatures, and gelatinization enthalpy (ΔH, J/g) of starch granule were calculated by TA Thermal System Software (Muse version 1.6,SIINT, Japan, 2012).

2.6. Pasting properties

The pasting profiles were analyzed using a rapid visco-analyzer (Model RVA-4C, Newport Scientific Pty. Ltd., Warrriewood, Australia). The starch concentration used in the present study was 8% (Dry weight, 28 g total weight). The suspension was stirred manually using the plastic paddle before the RVA run. Test profile was programmed according to the general pasting method (Standard 2). The slurries were first held at 50 °C for 1 min, heated at a rate of 6.0 °C/min to 95 °C, maintained at that temperature for 5 min, cooled to 50 °C at a rate of 6.0 °C/min and held at 50 °C for 2 min. Constant paddle rotating speed (160 rpm) was used throughout the entire analysis except for a speed of 960 rpm for the first 10 s to disperse the samples. The average values for peak viscosity, PV, trough viscosity, TV, final viscosity, FV, pasting temperature, PT, breakdown, BV, and setback viscosity, SV were obtained for each sample from triplicate measurements.

2.7. Reconstituted bread procedure

The dough was made as described by Tao, Wang, et al. (2015) and Tao, Yan, et al. (2015) using a Brabender Farinograph-E (Brabender, OHG, Duisberg, Germany). The reconstituted flour consisted of wheat starch and gluten in a ratio of 86/14 calculated on dry basis content. All fractions (300 g reconstituted flours + 4.5 g yeast + 10.5 g sugar + 4.5 g salt) were pre-mixed in a 300 g pin for 5 min to improve the homogeneity of the reconstituted product. Then the reconstituted flours were hydrated to 55% (dry matter base) for 6.5 min and moulded into 60 g pieces. Then they were proofed at 37 °C with 80% relative humidity for 90 min before baking (15 min, 210 °C). To evaluate the impacts of minor components, the starch fraction in the reconstituted blends was substituted with SDS-treated, freezing/thawing-treated and SDS + freezing/thawing-treated starches, respectively.

The following bread characteristics were assessed: weight, volume (rapeseed displacement), specific volume (volume/weight). Crumb firmness was determined in TA-XT plus analyzer (Perten Instruments, Hägersten, Sweden) after 2 h after baking. Two bread slices of 10 mm thickness were subjected to compression with a cylindrical probe of 25 mm diameter. A hardness parameter was obtained at a 50% of strain, pre-test speed 3 mm/s, test speed 1 mm/s, and post-test speed 5 mm/s. Three replications were performed for each sample.

2.8. Statistical analysis

Statistical analysis was performed using ORIGIN 8.0 (OriginLab Inc., Northampton, MA, USA). The data are expressed as means ± standard deviations of at least three independent determinations on one sample for each time period, and