Carbohydrate Polymers 134 (2015) 413–417

Contents lists available at ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Inhibition of wheat starch retrogradation by tea derivatives

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ARTICLE INFO

Article history:
Received 8 July 2015
Received in revised form 31 July 2015
Accepted 7 August 2015
Available online 13 August 2015

Keywords:
Tea
Wheat starch
Retrogradation
Retardation effect
Avrami equation

ABSTRACT

The effect of four industrial tea derivatives (tea polyphenols [TPS], tea water-soluble extracts [TSE], tea polysaccharides [TSS], and green tea powder [GTP]), on the retrogradation of wheat starch was investigated using texture profile analysis (TPA), differential scanning calorimetry (DSC), rapid viscosity analysis (RVA), and the α-amylase–iodine method. The addition of the four tea derivatives resulted in decreased hardness and increased cohesiveness of the starch gel as shown by the TPA test. The DSC data demonstrated an increase in the enthalpy change of starch gelatinization and a decrease in the enthalpy change of starch recrystallite dissociation. The RVA results indicated that the peak viscosity, representing the intermolecular forces of wheat starch, was reduced after addition of TPS, TSE, and TSS, respectively, but was increased by GTP. Furthermore, the half crystallization time in the Avrami equation almost doubled after the separate addition of the tea derivatives.

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1. Introduction

Tea is produced from the plant *Camellia sinensis*, which mainly grows in China and in Southeast Asia. Tea provides many health benefits, such as antioxidant properties, hypertension prevention, ultraviolet radiation protection, and bodyweight management (Cao, 2013; Pinto, 2013). These health benefits have been attributed to the bioactive components in tea, mainly polyphenols and polysaccharides. Due to these health benefits, tea is currently the most popular beverage in worldwide after water, and is thought to be the most promising natural product for health in the 21st century (Bansal et al., 2013; Narotzki, Reznick, Aizenbud, & Levy, 2012; Thielecke & Boschmann, 2009). However, when tea is incorporated into foods, its components often interact with other food ingredients, including starch. From the literature, tea polyphenols or tea polysaccharides have been shown to have the ability to modify the thermodynamic, paste, and retrogradation properties of starch (Ananingsih, Sharma, & Zhou, 2013; Guo, Liang, & Du, 2011; Guo, Zhu, & Du, 2013; Zhu, Cai, Sun, & Corke, 2009). It is thought that the modifications by TSS may result from increased electrostatic repulsion and decreased association among the macromolecules, as well as synergistic interactions among these polysaccharides. As for TPS, its polyhydric structures could have resulted in the increased enthalpy of starch gelatinization and decreased starch retrogradation (Wu, Chen, Li, & Li, 2009; Zhu, Cai, Sun, & Corke, 2008). Furthermore, it is likely that tea protein and/or fiber, as well as other tea components, can affect the physicochemical properties of starch, though there is little published data on these theories. In the previous studies, many factors and compounds are thought to be able to eliminate or reduce starch retrogradation in both short- or long-term retrogradation, including β-cyclodextrin (Tian et al., 2009a,b), anionic polysaccharides (Funami et al., 2008), and food hydrocolloids (Funami et al., 2005).

Recently, bakery products contained tea components were privilege in the market for its healthy benefits. However, the quality especially the storage properties of this kind high-starch products was decreased by starch retrogradation. The objective of this research, therefore, was to give a scientific insight of four typically industrial tea derivatives (TPS; tea water-soluble extracts (TSE); TSS; and green tea powder (GTP)) as potential anti-retrogradation additives in food industry. The retarding effect of above four typically industrial tea derivatives on both the short- and long-term retrogradation of wheat starch (WS) were evaluated and compared, using texture profile analysis (TPA), differential scanning calorimetry (DSC), rapid viscosity analysis (RVA), and the α-amylase–iodine method.

2. Materials and methods

2.1. Materials

WS (amylose content 22.7% dry basis (d.b.), amylopectin content 75.3% (d.b.), and protein content 1.5% (d.b.)) was purchased from Yongsheng Starch Food Company, Ltd (Hangzhou, Zhejiang, China).

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http://dx.doi.org/10.1016/j.carbpol.2015.08.018
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GTP (volume–surface average diameter $D^{[2,3]}$ = 20 μm, polyphenol content 14.4%, polysaccharide content 8.7%, protein content 31.3%, crude fiber content 23.6%, with the rest consisting of mainly caffeine and amino acids 22.0% d.b.) were ground at Hangzhou Tea Research Institute, China Coop (Zhejiang, China). TSE (polyphenol content 43.5% d.b., polysaccharide content 38.2% d.b., with the rest consisting of mainly caffeine and amino acids 18.3% d.b.), TPS (polyphenol content 91.2% d.b., with the rest consisting of mainly caffeine and amino acids 8.8% d.b.), and TSS (polysaccharide content 81.3% d.b., with the rest consisting of mainly amino acids and protein 18.7% d.b.) were purchased from Zhejiang Orient Tea Development Co., Ltd (Hangzhou, Zhejiang, China). Highly purified α-amylase (E.C. 3.2.1.1. 1400 unit/mg solid) was obtained from *Bacillus* species from Sigma Chemical Co. (Shanghai, China.). All other chemicals and reagents were of analytical grade unless otherwise stated.

2.2. Preparation of gelled and retrograded WS samples

Twenty-five grams of WS was divided into five even portions. Four of the portions were added to 10.0 mL of water containing the equivalent of 100.0 mg GTP, TSE, TPS, and TSS, respectively. The suspensions were gently shaken in boiling water until the water content decreased to 40% of the total weight of the suspension. The same amount of WS, without any additives, was treated similarly to act as the control. To accelerate the retrogradation process, the gelatinized samples were stored at 4 °C in sealed containers to avoid moisture loss over the experimental period. Then, the gelatinized samples were evenly dehydrated at 45 °C in a vacuum oven; the dried samples were then milled and passed through a 100-mesh sieve.

2.3. Texture profile analysis

A texture analyzer TA-XT2i (Stable Micro Systems, Surrey, UK) was used to obtain the force–time curve according to Tian et al. (2009b). Briefly, the gelatinized gels were compressed twice under a cylindrical probe 5 mm in diameter at a test speed of 1 mm/s and a control force of 10 g. The deformation level was 25% of the original gel height. The gels were tested in triplicate for hardness, cohesiveness, springiness, and chewiness, to evaluate the retrogradation of the starch mixtures.

2.4. Differential scanning calorimetry

Thermal analysis was performed using a Pris 1 differential scanning calorimeter (PerkinElmer, Inc., Waltham, MA, USA) following the method by Tian et al. (2009b). In details, the whole determination was carried under an ultrahigh-purity nitrogen atmosphere. The equipment was calibrated with indium and tin standards. The gelatinized WS gels (3 mg) and distilled water (6 μL) were together placed in an aluminum pan. The sealed samples were equilibrated for 12 h at 25 °C and then heated from 25 to 110 °C at a constant rate of 5 °C/min to collect data on the thermal enthalpy changes. An aluminum pan containing same amount of distilled water was used as a reference.

2.5. Rapid viscosity analysis

The pasting properties of the starch blends were determined using a Rapid Visco-Analyzer (Newport Scientific Pty. Ltd., Warriewood, NSW, Australia) as outlined by Lin, Kao, Tsai, and Chang (2013). Briefly, each starch mixture suspension (1.5 g WS mixture into 25 mL water in a cuvette) was equilibrated at 50 °C for 1 min, heated to 95 °C at a rate of 10 °C/min, maintained at 95 °C for 6 min, then cooled to 50 °C at a rate of 10 °C/min, and maintained at 50 °C for 1 min. The parameters recorded were peak viscosity (P), hot paste viscosity (H) (minimum viscosity at 95 °C, or breakdown viscosity), final viscosity (F), breakdown ($B = P - H$), and setback ($S = F - H$).

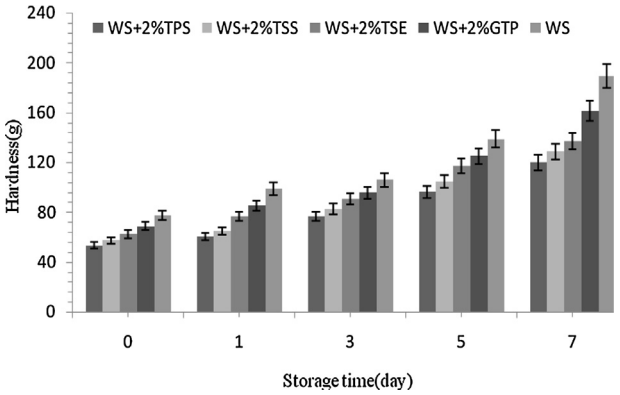

Fig. 1. Changes in the hardness of starch gels over 7 days' storage (WS: wheat starch; WS + 2% TPS: wheat starch with addition of tea polyphenols; WS + 2% TSS: wheat starch with addition of tea polysaccharides; WS + 2% TSE: wheat starch with addition of tea water-soluble extracts; and WS + 2% GTP: wheat starch with addition of green tea powder).

2.6. Determination of retrogradation degree using the α-amylase–iodine method

The retrogradation degree (R) of the WS mixtures was evaluated using the α-amylase–iodine method previously described by Kim, Kim, and Shin (1997). The degree of starch retrogradation was expressed by the change in gelatinization. The data were then analyzed using the Avrami equation.

2.7. Statistical analysis

The data are expressed as the mean ± SD of three analyses for each sample unless otherwise stated. Statistical significance was assessed with one-way analysis of variance using SPSS 16.0 software (SPSS, Inc., Chicago, IL, USA). The treatment means were considered statistically significantly different at $p < 0.05$. The figures were plotted by ORIGIN 8.0 (Origin Lab Inc. USA) in Win7 system.

3. Results and discussion

3.1. Texture profile analysis

According to previous studies, the hardness of starch gel in storage is highly correlated to retrogradation, and can thus be used to gauge the degree of retrogradation (Tian et al., 2009a,b). All the tested samples tended to become harder over the 7 days' storage (Fig. 1). The starch gel samples with added tea derivatives were softer than the starch-only samples at any given time, which suggests that tea derivatives could potentially be used to reduce the hardness of WS gel during storage. The degree of softening differed among the different tea derivatives (TPS, TSS, TSE, and GTP). WS with TPS had the lowest hardness, followed by TSS, TSE, and GTP.

Cohesiveness is associated with intramolecular interactions. Fig. 2 shows that separate addition of TPS, TSS, TSE, and GTP, increased the cohesiveness of the starch gel over the same period of time. This increase indicates strong intramolecular interactions in the starch samples. Among the tested tea derivatives, starch with TSS clearly had higher cohesiveness than the other samples.

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