LWT - Food Science and Technology 64 (2015) 205–211

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effect of tapioca starch addition on rheological, thermal, and gelling properties of rice starch

D. Sun, B. Yoo*

Department of Food Science and Biotechnology, Dongguk University-Seoul, Seoul 100-715, Republic of Korea

ARTICLE INFO

Article history:
Received 20 January 2015
Received in revised form
27 May 2015
Accepted 29 May 2015
Available online 9 June 2015

Keywords:
Rice starch
Tapioca starch
Starch blend
Rheological property
Thermal property

ABSTRACT

The rheological, thermal, and gelling properties of blends of rice starch (RS) with tapioca starch (TS) at different RS/TS ratios (10/0, 9/1, 8/2, 7/3, 6/4, and 5/5) were examined. Steady and dynamic shear rheological tests indicated that the consistency index (K) and yield stress (σ_{oc}) of the RS–TS blends increased with an increase in the mixing ratio of TS while the dynamic moduli (G' and G'') values decreased. Tan δ (ratio of G''/G') values of all the blends were higher than that of RS, indicating that there is a more pronounced synergistic effect on the viscous properties of RS in the presence of TS. DSC studies found that the transition temperatures and enthalpies of gelatinization of the blends appeared to be greatly influenced by the addition of TS. The blend gels showed higher gel strength and also better freeze–thaw stability with a significant decrease in syneresis (%) in higher ratios of TS. In general, these results suggest that in the RS–TS blend systems, the addition of TS modified the rheological, thermal, and gelling properties of RS, and that these modifications were dependent on the mixing ratio of TS as well as the physical properties of the two component starches.

1. Introduction

Starch has been widely used and is a very important ingredient in the food industry because of its thickening and gelling properties. It is also known that native starches are limited in their food applications due to their heat, shear, and acid instability associated with the processing conditions, even though they can provide thickening, bulk, and body as well as improved texture with the advantages of lower cost and easier handling and processing (BeMiller & Whistler, 2007). Therefore, native starches are often chemically modified to expand the range of their applications in the food industry because the chemical modifications can increase the resistance to shear, acid, and high temperature, reduce retrogradation, and improve freeze–thaw stability (Waterschoot, Gomand, Willebrords, Fierens, & Delcour, 2014). However, recently, interest in finding new ways to improve the rheological and physical properties of native starches without using chemical modifications has grown due to the increased consumer demand for natural food ingredients and products (Zhang, Gu, Hong, Li, & Cheng, 2011).

As an alternative approach to chemical modifications, native starch blends are frequently employed in starch-based food products to provide desirable physical and rheological properties because these blends may influence the viscosity and retrogradation of starch pastes, as well as the syneresis of starch gels (Puncha-Arnon, Pathipanawat, Puttanlek, Rungsardthong, & Uttapap, 2008). It may also offer an economic advantage when a more expensive starch can be partially replaced by a cheaper alternative without affecting product quality (Waterschoot et al., 2014). Several researchers have studied the gelatinization behaviors (Gunaratne & Corke, 2007; Ortega-Ojeda & Eliasson, 2001; Puncha-Arnon et al., 2008; Zhu & Corke, 2011), pasting properties (Gunaratne & Corke, 2007; Lin, Kao, Tsai, & Chang, 2013; Obanni & Bemiller, 1997; Park, Kim, Kim, & Lim, 2009; Waterschoot et al., 2014; Zhang et al., 2011), and rheological properties (Ortega-Ojeda & Eliasson, 2001; Sasaki, Yasui, Matsuki, & Satake, 2002; Zhang et al., 2011) of various starch blends. They found that the use of starch blends instead of starch alone provided great benefit in terms of pasting, gelatinizing, and rheological properties, and that these effects were dependent on the type of starch and the concentration of starch added. However, to the best of our knowledge, no comprehensive research has been reported to date on the rheological and physical properties of blended pastes of rice starch (RS) and tapioca starch (TS) in order to expand the industry application of RS by improving

---

* Corresponding author. Department of Food Science and Biotechnology, Dongguk University-Seoul, 3 Pil-dong, Chung-gu, Seoul 100-715, Republic of Korea. Tel.: +82 2 2260 3368; fax: +82 2 2264 3368.
E-mail address: bsyoo@dongguk.edu (B. Yoo).

http://dx.doi.org/10.1016/j.lwt.2015.05.062
0023-6438/© 2015 Elsevier Ltd. All rights reserved.

its functional properties or reducing its undesirable properties. In Asian countries, RS is mainly used as a primary ingredient in processed rice products, such as rice cakes, soup, snack food, noodles, baby food, and breakfast cereals. TS was chosen for the present study because it has been used in numerous industrial and food applications, including as a thickening and gelling agent and an adhesive for paper, and its price in the world market is low compared to other starches (Chaisawang & Suphantharika, 2006). In the starch blend systems, TS is normally added into the preparation of starch-based products with expanded, porous and low density characteristics because it gives high expansion (Tongdang, Meenun, & Chainui, 2008).

The main objective of this study was to investigate the rheological, thermal, and gelling properties of blends of RS and TS at different RS/TS ratios. In addition, information about the modification of the gelatinization, rheological, gelling properties of blends of RS and TS at different RS/TS ratios will be helpful in understanding their structural and functional properties, and also in improving the rheological and physical properties of RS-based products for further application in product development.

2. Materials and methods

2.1. Materials and starch isolation

Rice was purchased from a rice farm in Cheongpyung, Gangwon, Korea, and was milled and ground into flour at a local mill. Rice starch (RS) was isolated from the rice flour according to the alkaline method reported by Yamamoto, Sawada, and Onogaki (1973), with minor modifications. Rice flour was suspended in 0.2 g/100 g NaOH solution with mild stirring for 1 h at 25 °C. The suspension was then centrifuged at 1800 × g for 20 min and the supernatants were discarded. The alkaline treatment was repeated seven times, after which the recovered starch suspension was neutralized to pH 7.0 with 0.1 N HCl. The isolated starch was washed three times with distilled water and then dried in an oven drier at 40 °C. The dried starch was ground and then passed through a 100-mesh standard sieve (Chung Gye Inc., Seoul, Korea) with 150 μm openings using an analytical sieve shaker (Model AS200, Retsch GmbH & Co., Haan, Germany). Its proximate composition was: 10.9 g/100 g moisture, 5.6 g/100 g protein (N × 6.25), 0.9 g/100 g fat, 0.24 g/100 g ash and 81.26 g/100 g carbohydrate (by difference), and amylose content was 15.0 g/100 g. Tapioca starch (20.8 g/100 g amylose content) was provided from AVEBE, Inc. (Veendam, The Netherlands).

2.2. Preparation of starch pastes

Blends of RS with TS were prepared at ratios of 9/1, 8/2, 7/3, 6/4, and 5/5 (RS/TS) based on dry weight by mixing each in a mixer. The starch blend dispersions (5 g/100 g) were prepared by mixing the blended samples with distilled water. RS and TS dispersions were also prepared for comparison with the RF–TS blends. Each blend was moderately stirred in an Erlenmeyer flask with a screw cap for 1 h at room temperature and then heated at 95 °C in a water bath for 30 min with mild agitation provided by a magnetic stirrer. These hot pastes (95 °C) were then used to examine the steady and dynamic shear rheological properties of RF–TS blends.

2.3. Swelling power and solubility

The swelling power and solubility of RS, TS, and blend samples were determined as described by Leach, McCowen, and Schoch (1959). A sample dispersion at 0.5 g/100 g was prepared by mixing the sample with distilled water. The dispersion was then moderately stirred for 1 h at room temperature, followed by being heated at 95 °C in a water bath for 30 min. The hot paste was cooled to room temperature in an ice water bath and centrifuged at 2100 × g for 20 min. The supernatant was decanted and the swelling power was defined as the ratio of the weight of the sediment to the weight of dry sample. An aliquot of the supernatant was then evaporated for 4 h in a vacuum oven at 120 °C. The solubility was determined to be the ratio of the weight of the dried supernatant to the weight of dry sample. All measurements were made in triplicate.

2.4. Steady and dynamic shear rheological properties

The steady shear rheological properties of the RS–PS blends were observed under both steady and dynamic shear conditions, as described in a previous study (Chun & Yoo, 2004). A rotational concentric cylinder viscometer (VT550 Haake, Haake Inc., Karlsruhe, Germany) was used to measure the steady shear rheological properties. The measuring system (MV2) consists of a rotating cylinder with an 18.4 mm radius, a length of 60 mm, and a gap width of 2.6 mm. Temperature control was carried out with a constant temperature circulator (Model DS50-K10, Haake GmbH, Karlsruhe, Germany) which provide a working temperature range of 0–90 °C (±0.1 °C). The hot pastes (as described earlier) were immediately transferred to a viscometer cup for the measurements of steady shear rheological properties at 25 °C. The sample was sheared continuously from 0.4 to 300 s^{-1}. Each measurement was taken after 20 min after loading which also allowed for temperature equilibrium. As a means to describe the variation in the rheological properties of RS–TS blend paste under steady shear, the data were fitted to the well-known power law model (Eq. (1)) and Casson (Eq. (2)) models in order to illustrate the steady shear rheological properties of the samples, which are as follows:

$$\sigma = K\dot{\gamma}^{n} \tag{1}$$

$$\sigma_{0.5} = K_{oc} + K_c\dot{\gamma}^{0.5} \tag{2}$$

where σ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency index (Pa s^n), n is the flow behavior index (dimensionless), and $(K_c)^2$ is the Casson plastic viscosity (η_c). Casson yield stress (σ_{oc}) was defined as the square of the intercept (K_{oc}), which was obtained from a linear regression of the square roots of shear rate–shear stress data.

Dynamic shear rheological properties were carried out using an AR 1000 rheometer (TA Instruments, New Castle, DE, USA) with the plate–plate geometry (diameter 4 mm; gap 500 μm). Temperature was controlled by a water bath connected to the Peltier system in the bottom plate. Dynamic shear data were obtained from the frequency sweeps over the range of 0.63–62.8 rad s^{-1} at the 2% strain, which was in the linear viscoelastic region. Frequency sweep tests were also conducted at 25 °C. The TA rheometer Data Analysis software (ver. VI. 1.76) was used to obtain the experimental data as well as to calculate the storage modulus (G′), loss modulus (G″), and loss tangent ($\tan \delta = G''/G'$). All samples were allowed to rest for 5 min at their initial temperatures prior to the steady and dynamic shear rheological measurements. Additionally, all rheological measurements were performed in triplicate.

For G′ measurements in the aging process at 4 °C, each sample was loaded onto the 4 °C platen of the rheometer and the exposed sample edge was covered with a thin layer of light paraffin oil to prevent evaporation during measurements. G′ values were monitored for 10 h at 6.28 rad s^{-1} and 2% strain. The rheological measurements during aging were conducted in duplicate.