LWT - Food Science and Technology 66 (2016) 530–537

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Correlation between physicochemical properties of *japonica* and *indica* rice starches

Eun-Hee Jang [a, 1], Su-Jin Lee [a, b, 1], Joo-Yeon Hong [a], Hyun-Jung Chung [c], Young-Tack Lee [d], Bo-Sik Kang [a], Seung-Taik Lim [a, *]

[a] School of Life Sciences and Biotechnology, Korea University, Seoul 136-701, Republic of Korea
[b] Department of Food Preparation, Suseong College, Daegu 706-711, Republic of Korea
[c] Division of Food and Nutrition, Chonnam National University, Gwangju 500-757, Republic of Korea
[d] Department of Food Science and Biotechnology, Gachon University, Gyeonggi-do 461-701, Republic of Korea

ARTICLE INFO

Article history:
Received 28 July 2015
Received in revised form
8 October 2015
Accepted 1 November 2015
Available online 10 November 2015

Keywords:
Rice starches
Amylose content
Thermal properties
Pasting properties
Textural properties

ABSTRACT

Rice starches isolated from different cultivars were compared in their physicochemical properties including granule size, amylose content, protein content, thermal property, pasting viscosity, and gel texture, and the relationships among those properties were determined using Pearson correlation analysis. The starch containing the greatest amount of amylose which had been isolated from a *japonica* cultivar *Goami 3* showed the highest gelatinization temperature and the greatest gel hardness among twelve rice starches tested. The *indica* starches which contained the higher amylose and protein contents and the larger granules than *japonica* starches showed the higher gelatinization and pasting temperatures with the lower pasting viscosity. Amylose content was positively correlated to pasting temperature ($r = 0.878$, $p \leq 0.01$), but negatively correlated to peak viscosity ($r = -0.910$, $p \leq 0.001$) and breakdown ($r = -0.905$, $p \leq 0.001$). Cohesiveness of starch gel was positively related to amylose content ($r = 0.780$, $p \leq 0.05$), protein content ($r = 0.933$, $p \leq 0.001$) and mean granule size ($r = 0.791$, $p \leq 0.05$).

1. Introduction

Rice is an important staple food in many Asian countries, contributing as a major calorie source. Although most of the rice harvested in the world is consumed in the form of milled kernels, some starch is isolated from rice, and commercialized for different applications in several Asian and European countries. Its utilization is much less than other cereal starches from corn and wheat, rice starch has some desirable properties such as bland taste, white color and good digestibility. Moreover, its small granule size makes the starch advantageous in utilizing as a texture improver in a variety of foods such as sauces and puddings, or as a fat substitute in dressings and creams (Mitchell, 2009). It is hypoallergenic as it contains almost no specific proteins that cause allergic responses to human, so that infant formula would be one of the ideal products for the use of rice starch. Furthermore, rice starch containing a relatively high level of amylose was reported to display relatively low glycemic index (Champagne, 1996), which is desirable when consumed by diabetes or obese people. These unique characteristics of rice starch make it a better option than the common corn and wheat starches, in various food applications. However, the production of rice starch is limited and its price is much higher than that of corn or wheat starch.

Rice starch is composed of amylose and amylopectin and often distinguished by its amylose content. Rice starches with amylose contents of 0–2, 5–12, 12–20, 20–25, and 25–33% have been classified as waxy, very low, low, intermediate and high amylose rice starches, respectively (Juliano, 1992). Amylose content of *indica* rice starch is generally higher than that of *japonica* rice starch (Inouchi et al., 2005; Takeda, Hizukuri, & Juliano, 1987). Physical properties of starch in pastes and gels are influenced by the amylose content, chain structure of starch, and granule size of starch. In addition to the amylose content, residual protein in starch affects the pasting characteristics of starch (Lim, Lee, Shin, & Lim, 1999). These inherent characteristics determining the physical properties of starch are usually attributed to their botanical origins (Champagne, 1996; Jane et al., 1999; Madsen & Christensen, 1996; Singh, Singh, Kaur, Sodhi, & Gill, 2003). The gelatinization and

* Corresponding author. Tel: 82-2-3290-3435; Fax: 82-2-921-0557.
E-mail address: limst@korea.ac.kr (S.-T. Lim).
[1] Eun-Hee Jang and Su-Jin Lee contributed equally.

http://dx.doi.org/10.1016/j.lwt.2015.11.001
0023-6438/

pasting properties of starch, which are the most important characteristics for thermal processing, depend largely on the granular structure and starch composition (Bao, Shen, Sun, & Corke, 2006; Jane et al., 1999; Lim et al., 1999; Park, Ibáñez, Zhong, & Shoemaker, 2007; Vandeputte, Vermeylen, Geeroms, & Delcour, 2003; Wang et al., 2010). However, physicochemical properties of various starches from *japonica* and *indica* rice cultivars imported by different countries and statistical analysis for the relationship among those properties have not been studied. In the situation that Korean rice market must be fully opened in 2015, information on the physicochemical properties of starches from diverse rice cultivars is necessary to predict the functionality and potential application of Korean rice starches in processed food products.

The objectives of this study were to examine and compare the physicochemical characteristics such as amylose content, protein content, granule size, thermal properties, pasting viscosity, and gel textural properties of different starches from *japonica* and *indica* rice cultivars. The relationships among those properties were also determined using Pearson correlation analysis.

2. Materials and methods

2.1. Rice samples

Six non-waxy *japonica* rice cultivars (*Baegjinju 1*, *Chucheong*, *Goami 3*, *Haiami*, *Yeongan*, and *Hyangmi 1*) and three waxy *japonica* rice cultivars (*Dongjinchal*, *Aranghyangchal* and *Baekokchal*) harvested at 2011 in Korea were obtained from the National Institute of Crop Science (Suwon, Korea). Three *indica* rice cultivars were purchased from different companies: a non-waxy Chinese rice cultivar (*Jiangxi)* from Qingdao Ever-Success Trading Co., Ltd. (Qingdao, China), a non-waxy American rice cultivars (*Cop 18*) from Creative BioMart Biosciences Inc. (Shirley, NY, USA), and a waxy rice cultivar (*Remyline XS*) from BENEO-Remy NV (Leuven-Wijgmaal, Belgium).

2.2. Starch isolation

Starch was isolated from rice flours by using the alkaline steeping method (Lim et al., 1999). Rice flour (100 g, db) was dispersed in a dilute sodium hydroxide solution (0.2 g/100 g, 300 mL) using a magnetic stirrer at 25 °C for 1 h. The dispersion was centrifuged (1800 × g for 10 min), and then fresh alkaline solution (0.2 g/100 g NaOH, 300 mL) was added to the precipitate to repeat the extraction process. After three cycles of extraction, starch precipitates were re-suspended in 200 mL of distilled water and neutralized to pH 7.0 by adding 0.1 mol/L HCl solution. The neutralized starch residue was washed twice with distilled water (200 mL each) and finally with 200 mL of 95 g/100 g ethanol. The starch collected by centrifugation was dried in a convection oven at 40 °C overnight.

2.3. Amylose and protein contents

Amylose content in rice starch samples was measured after an enzymatic debranching using a gel permeation chromatography which consisted of a pump (P2000, Spectra System, San Jose, CA, USA), an injector valve with a 0.1 mL loop (Rheodyne 7072, Cotati, CA, USA), and a refractive index detector (Shodex RI-71, Tokyo, Japan). The column used was a medium-pressure Superdex 75HR (Amersham Pharmacia Biotech, Uppsala, Sweden). The eluent was deionized water containing 0.02 g/100 g NaN_3 that had been filtered through a 0.1-μm cellulose acetate filter (Whatman, Maidstone, UK) and degassed. The flow rate of the eluent was 0.3 mL/min.

All starch samples for amylose analysis were purified by dissolving in 90 g/100 g DMSO and isolated by adding absolute ethanol (Jane & Chen, 1992). The purified starch (50 mg, db) was dispersed in deionized water (25 mL), and the dispersion was then autoclaved at 121 °C for 15 min for complete dissolution. Acetate buffer (0.1 mol/L, pH 3.5, 200 μL) and isoamylase (0.3 μL, 280 U/mg) were added to the starch solution, and the mixture was incubated at 45 °C for 24 h in a shaking water bath. The enzyme was inactivated by boiling the solution for 15 min. The debranched starch solution was filtered through a 5.0-μm acrylic copolymer syringe filter (Pall Gelman Science, Ann Arbor, MI, USA) before GPC analysis.

Crude protein content was determined using an auto-Kjeldahl system (AutokjelTech, Model No. 11, Tecator, Hsiganas, Sweden).

2.4. Particle size analysis

The particle size distribution was measured with an aqueous suspensions of starches using a laser diffraction particle size analyzer (CILAS 1064, Compagnie Industrielle des Lasers, Orléans, France). The mean diameter (D_{50}) of rice starches was determined by the particle size distribution by volume.

2.5. Thermal properties

The gelatinization temperature and enthalpy of rice starches were measured using a differential scanning calorimeter (DSC6100, Seiko Instruments Inc., Chiba, Japan). The instrument was calibrated with indium and an empty aluminum pan was used as the reference. Starch sample (3.0 mg, db) and water (6.0 mg) were transferred to an aluminum DSC pan. The pan was then sealed and equilibrated at 4 °C for 2 h prior to analysis. The sample pan was heated at a speed of 5 °C/min from 20 to 130 °C. The onset (T_o), peak (T_p), and conclusion (T_c) temperatures along with gelatinization enthalpy (ΔH) were determined from the thermograms.

2.6. Pasting viscosity

Pasting viscosity of the rice starches was evaluated with a Rapid Visco-Analyzer (RVA-3D, Newport Scientific, Warriewood, Australia). Starch suspensions (7 g/100 g, w/w) were heated using a programmed heating and cooling cycle: heating from 50 to 95 °C at a rate of 13 °C/min, holding at 95 °C for 3 min, cooling to 50 °C at 13 °C/min, and holding for 4 min. A constant rotating speed of the paddle (160 rpm) was used. Values of peak viscosity, breakdown, setback, final viscosity and pasting temperature were obtained from the viscograms.

2.7. Gel texture

Starch suspensions (13 g/100 g, w/w) were heated from 25 to 95 °C at a rate of 14 °C/min and held at 95 °C for 10 min using a Rapid Visco-Analyzer. The starch paste was transferred into petri dishes (50 mm diameter, 0.9 mm depth) taped around the edge. After cooled by leaving at room temperature for 1 h, the petri dishes were covered and then stored at 4 °C for gel formation. The texture of the starch gels was measured using a texture analyzer (TA-XT2, Stable Microsystems, Surrey, England). After the top portion above the edge was removed with a wire cheese cutter to make the gel surface smooth, the gel was compressed at a speed of 1.0 mm/s with a cylindrical plunger (20 mm diameter). The parameters analyzed included hardness, chewiness, gumminess, springiness, and cohesiveness.

2.8. Statistical analysis

All experiments were performed in triplicates. The data were