Effect of high speed jet on the physical properties of tapioca starch

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ABSTRACT

Tapioca starch-water suspension was subjected to high speed jet (HSJ) treatment and the physical properties were investigated by Particle size analysis, Differential scanning calorimetry (DSC), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and Scanning electron microscope (SEM). Particle size analysis revealed a significant increase in volume mean diameter from 17.00 to 40.35 μm. SEM studies showed that treated tapioca starch (TS) was prone to aggregate with each other and markedly damaged at starch granule surface which eventually disintegrated into gel-like structures at high pressure level. XRD patterns showed that all samples exhibited A-type and there was an evident loss of crystallinity after treated over 160 MPa. The TS showed similarity on FTIR spectral pattern but had different intensity in some peaks at increasing pressure. DSC analysis confirmed that TS was partly gelatinized after HSJ treatment, and the degree of gelatinization increased to $34.34 \pm 1.0\%$ when the pressure was 240 MPa. These results provided the basic information on the physical properties of TS treated at different pressures and indicated the potential possibility of HSJ for starch modification.

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1. Introduction

Starch is one of the most abundant natural resources and also an important biopolymer which has been widely used in food industry such as paper, thickener and gelling agent (Hoover, 2001; Liu & Zhang, 2006). However, the application of native starches using in the food industry have some limitations due to the poor solubility, uncontrolled paste consistency (Choi, Kim, Park, Kim, & Baik, 2009) and lack of stability under conditions of shear, acid pH and refrigeration (Liu, Zhang, Shen, Hu, & Wu, 2012). In order to overcome these limitations, various treatments (physical, chemical, and enzymatic) have been used to modify its structure to obtain some functional properties in accordance with the requirement of specific industrial applications (Tu et al., 2013).

High-pressure (HP) technology with combination of high pressure, high shear and cavitation, has been considered as a useful technique in modifying starches among various physical modification treatments (Liu, Hu, & Shen, 2010). It has been shown in many papers reporting the effect of HP modification methods on structure and physicochemical properties of starch. Wang, Li, Wang, Liu and Adhikari (2012) reported that high-pressure homogenization (HPH) treatment is capable of inhibiting high-amylose maize starch retrogradation in gels. Ahmed, Singh, Ramaswamy, Pandey, and Raghavan (2014) declared that native starch produced the strongest gel rigidity and the storage modulus of starch gels increased with pressure at 400–600 MPa. Kawai, Fukami, and Yamamoto (2007) revealed that the value of ΔHgel of potato starch-water mixtures decreased with increased pressure and temperature, while the value of ΔHretro tended to increase with increase in starch content after treated by high hydrostatic pressure at different temperature (20–70 °C). According to Tu et al. (2013) and Kasemwong, Ruktanonchai, Srinuanchai, Itthisoponkul, and Sriroth (2011), the mean diameter and gelatinization temperatures of maize amylose and cassava starch decreased with increasing pressure of Dynamic high-pressure microfluidization (DHPM).

High speed jet (HSJ) is a novel device combination with high pressure and speed, and the main parts of it are shown in Fig. 1 (Soon, Harbidge, Titchener-Hooker, & Shamlou, 2001). The principle of operation consists of a piston chamber where crude suspension is drawn into through downward stroke. The suspension is forced to pass through a small fixed nozzle producing a high speed
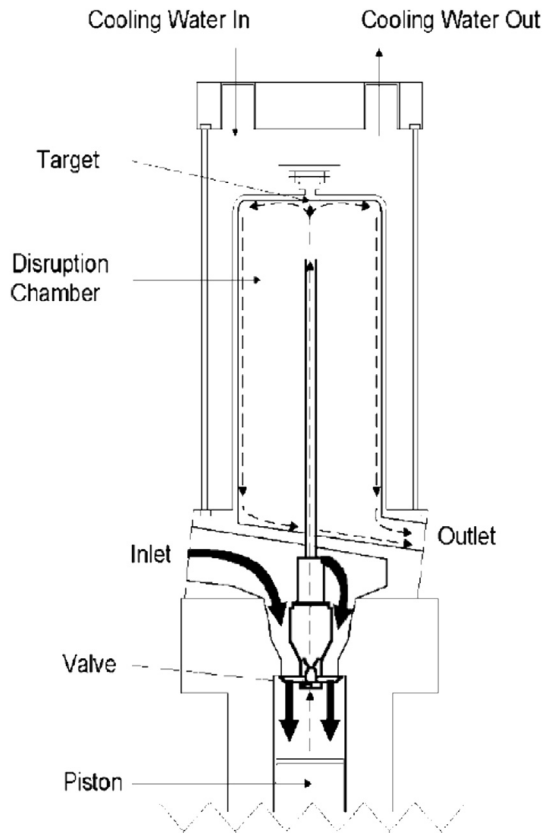
Fig. 1. The key components of high speed jet (HSJ) (Soon et al., 2001).

jet during the upward stroke. Before colliding on the target the jet travels through a pipe with varying cross sectional area and then cooled by a re-circulating flow of coolant from the walls of the disruption chamber. The available orifice diameters are in the range of 0.1–0.18 mm and the operating pressure ranges from 0 to 270 MPa which is higher than various treatments of HP technology such as DHPM. It suggests that HSJ is an intense mechanical treatment which is capable of affecting the size and gelatinization properties of starch polymer.

Although there are a lot of published reports that have focused on high pressure processed starch, the effect of HSJ on the structure and properties of starch were rarely studied. The aim of this study was to investigate the effect of HSJ on the physical properties of tapioca starch at different pressure from 80 to 240 MPa. Tapioca (obtained from cassava root − *Manihot esculenta*) starch was used in this study as it is widely produced in Latin America, Africa and Asia, and also is one of the most important crops used in several industries (Piyachomkwan et al., 2002). After HSJ treatment, the starch samples were investigated by particle size analysis, XRD, FTIR, DSC, and SEM. The results could provide some informations of the HSJ effects on tapioca starch and they are expect to explore the potential possibility of HSJ for starch modification, and expand its applications in starch processing industry.

2. Materials and methods

2.1. Materials

The purity degree of tapioca starch (Thai World Import and Export, Bangkok, Thailand) was 99.7% (dry weight basis) and it was purchased from a food factory in Thailand. The moisture content of tapioca starch was 14.80% (w/w). All chemicals used were of analytical grade.

2.2. HSJ of tapioca starch suspension

Tapioca starch-water suspension (5% w/w) was prepared by adding tapioca starch with certain amount of deionized water at room temperature. Tapioca starch-water suspension was thoroughly mixed through a stirring rod and then treated by High Pressure Cell Disrupter (Constant Systems TS 1.1kw, UK) for one pass at 80, 120, 160, 200 and 240 MPa, respectively. Five hundred milliliters of suspension was processed at each pressure level. The samples after HSJ treatment were vacuum filtered, and then dried in an oven at 40 °C for 24 h. Dried samples were carefully pulverized with a mortar and pestle, and then stored in a desiccator for further characterizations.

2.3. Particle size analysis

The particle size analyzer (MS2000, UK) was used to analyze the particle size and the experiment was carried out according to the method of Li et al. (2013) and Wang et al. (2008). The wavelength was 632.8 nm and the scattering angle was 90°. The dry starch samples were dispersed in anhydrous alcohol in the diffractometer cell before measurements.

The density of tapioca starch was carried out according to the following method: a beaker with a certain amount of water was prepared and then tapioca starch was added into the breaker. The required bulk density of starch was determined from the weight and volume of starch in the beaker (Muramatsu, Tagawa, & Kasai, 2005). Every sample was replicated thrice. The particle size analysis was calculated by the instrument software.

2.4. SEM

Samples were mounted on aluminum nails and coated with platinum using an Ion Sputter E-100 coating system (Hitachi High-Technologies, Tokyo, Japan). Microstructural images were obtained from scanning electron microscope (S-4800, Hitachi Limited, Tokyo, Japan) at 1000 magnification and an accelerating voltage of 3.0 kV.

2.5. XRD analysis

X-ray diffractograms were obtained using a Siemens D5000 X-ray diffraction instrument (Rigaku Corporation, Japan) under the following conditions: 36 kV, 30 mA, one degree scattering slit, one degree divergence slit, 0.3 mm receiving slit. The relative intensity was recorded with the scanning angle 2 q set from 5° to 40° at a scanning rate of 0.6°/min. The area of crystalline fraction (ac) is divided by the diffraction area for a 100% crystalline substance (Ac), the Relative crystallinity (RC) of sample was estimated based on the method of Nara and Komiya (1983) using peak-fitting software (Origin 7.0, Microcal Inc., Northampton, MA). The ratio of the crystalline portion to sum of the crystalline and amorphous portions was calculated as crystallinity.

2.6. FTIR analysis

All infrared spectra were obtained on a Nicolet Nexus 470 spectrometer (Thermo Electron Corporation, Waltham, MA, USA) according to the method of Xia et al. (2014). The dried samples were ground with KBr powder (spectroscopic grade) and pressed into pellets for spectra measurement in the frequency range of