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Effect of high pressure on some physicochemical properties of several native starches

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Abstract

The impact of high pressure treatments (HPT) on some physicochemical properties of normal corn, waxy corn, wheat, and potato starches were studied. Three high pressure treatments were applied: HPT1 (740–880 MPa from 5 min to 2 h), HPT2 (960–1100 MPa for 24 h) and HPT3 (1500 MPa for 24 h). Using differential scanning calorimetry (DSC), it was found that the gelatinization temperature of starch was lowered by 3.0–6.6 °C after high pressure treatment and the corresponding gelatinization enthalpy was also reduced. In addition, these changes were irreversible and maintained during storage at 25 °C for up to 6 months. However, the birefringence of native and high pressure treated starch was not visually different in polarized light. For starches of same biological origin, their X-ray diffraction patterns were also similar. Using scanning electron microscopy (SEM), it was revealed that the high pressure treatments altered the shape of starch granules and changed their surface appearance.

Keywords: High pressure treatment; High pressure processing; HPP; Starch; Gelatinization; DSC; Birefringence; SEM; X-ray diffraction

1. Introduction

Starch is one of the very important biopolymers widely used in the food industry. Besides being an integral part of cereals, it has been used as thickener, bulking agent, gelling agent, colloid stabilizer, etc. Effect of high pressure on the alteration of physicochemical properties of various starches has been studied in the past several decades. Table 1 summarizes some publications in this area. Majority of the studies focused on starch-in-water suspensions with excess amount of water (30–99.6% w/w), where the effect of high pressure is on starch–water interaction i.e. so-called "high pressure induced gelatinization".

Muhr et al. (1982) studied the gelatinization of wheat, potato and smooth pea starches as a slurry of 33.3% solids over a pressure range of 0.1–400 MPa. They found that the gelatinization temperature first increased by a few degrees, and then became constant at 150–250 MPa, and then decreased slightly. In their experiment, the gelatinization enthalpies decreased with an increase in pressure, with the decrease being more rapid for wheat and smooth pea starches than for potato starch. Douzals et al. (1998) studied wheat starch-in-water suspensions of 5% solids under a pressure of 600 MPa at 25 °C for 15 min. They found that the wheat starch was completely gelatinized after the treatment. Kinetics of the high-pressure induced gelatinization of barley starch suspensions at two different concentrations (10% and 25%) were studied by Stolt et al. (2001) in a pressure range of 400–550 MPa. They found that rheological properties, microstructure and loss of birefringence, as well as melting of amylopectin crystals were all both pressure and time dependent. For the 10% suspension, only a slight increase in viscosity was observed, while a strong paste with a creamy texture and a maximum storage modulus of approximately 23 kPa was formed during pressurization of the 25% suspension. The rheological properties and microstructure of the pressure-induced gelatinized samples were different from those of heat-induced gelatinized samples. The starch granules remained intact after the

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Table 1
Some studies in the literature on the effect of high pressure on starch properties

Starch type	Pressure range	Starch content (w/w)	References
Potato	0–2500 atm	0.40%	Thevelein et al. (1981)
Wheat, potato, smooth pea	0.1–400 MPa	33.30%	Muhr et al. (1982)
Wheat, Potato	200–1500 MPa	55.5% or 12.7% for potato; 75.4%, 57.7%, or 13.3% for wheat	Muhr and Blanshard (1982)
Potato	800–1200 MPa	84.90%	Kudta and Tomasik (1992a)
Potato	800, 1000, or 1200 MPa	98–78%	Kudta and Tomasik (1992b)
Corn, waxy corn, amylocorn, rice, waxy rice, potato canna, lotus root, taro, tapioca, water chestnut, arrow root, and smooth peat starch	0–600 MPa	5–58%	Stute et al. (1996)
Barley	400-550 MPa	10% or 25%	Stolt et al. (2001)
Potato	600 MPa	10%	Blaszczak et al. (2005)
Potato, wheat, tapioca	0–700 MPa	5%	Bauer and Knorr (2005)
Maize	0.1–650 MPa	5%	Buckow et al. (2007)
Waxy corn, Hylon VII (high amylose corn)	650 MPa	70%	Blaszczak et al. (2007)
Potato	600, 800, 1000 MPa	10–70%	Kawai et al. (2007b)
Potato	0–1.2 GPa	10–70%	Kawai et al. (2007a)
Normal rice, waxy rice, normal corn, waxy corn, tapioca, potato	400 or 600 MPa	10%	Oh et al. (2007)
Rice	350–650 MPa	20%, 25%, and 33%	Ahmed et al. (2007)

pressure treatment and no leaching of amylose was observed. The retrogradation of pressure-induced gels was similar to that of heat-induced ones. Blaszczak et al. (2005) studied the effect of high pressure on the structure of potato starch in starch-in-water suspension (10%) under high pressure at 600 MPa for 2 and 3 min. They found that the high pressure significantly affected the amorphous and ordered structure. The gelatinization temperature and enthalpy were decreased upon high pressure treatment. They also found that the surface of starch granules was the most resistant to high pressure treatment while the inner part was almost completely filled with gel-like network, with empty spaces growing in diameter towards the center of the granule.

In most of the studies listed in Table 1, the effect of high pressure on starch-in-water suspensions depends on pressure range, application time and temperature. It was summarized by Knorr et al. (2006) as follows: when a starch suspension is heated while subjected to a pressure higher than 200 MPa, starch gelatinization could take place at a lower temperature range than when it is heated at ambient pressure; and if the pressure is high enough, the gelatinization can occur even at room temperature.

To our knowledge, the only study on starch in low water content (2–22% w/w) was by Kudta and Tomasik (1992a, 1992b), using 800–1200 MPa pressure for 60–600 s; and it was on potato starch only. They found that the properties of potato starch in low water content seemed to be changed by using high pressure pressing, and the amylopectin shell of the starch grains was the component that suffered most essential but rather random damage. The high pressure of 1000 MPa seemed to cause some repolymerization of dextrin formed during earlier compression. And the pressure of 1200 MPa caused further damage to the starch structure with the ordering of the molecules into more crystal-like matter. However, changes in the thermal property (i.e. gelatinization) of starch after high pressure treatment were not examined.

The study in this paper investigated how different high pressure treatments affect the physicochemical properties of several starches with low moisture content, while focusing on their gelatinization properties. Two types of high pressure processors were used. The investigated properties of starch before and after high pressure treatments include birefringence, X-ray diffraction, surface morphology, and gelatinization temperature and enthalpy. Meanwhile, changes in the effect induced by the high pressure treatments during storage were also studied.

2. Materials and methods

2.1. Materials

Normal corn starch and wheat starch were purchased from Suntop Enterprise, Singapore. Potato starch (Meelunie BV, Holland) was purchased from local market. MELLOJEL® normal corn starch and AMIOCA® waxy corn starch were obtained from National Starch & Chemical, Singapore. The solid contents of SUNTOP normal corn starch, MELOJEL® normal corn starch, AMIOCA® waxy corn starch, SUNTOP wheat starch, and potato starch were $86.0 \pm 0.1\%$, $85.8 \pm 0.2\%$, $84.9 \pm 0.4\%$, $85.6 \pm 0.2\%$, and $80.4 \pm 0.1\%$, respectively.

2.2. High pressure treatment and storage

Starch samples underwent three types of high pressure treatment, denoted as "HPT1", "HPT2" and "HPT3".

HPT1 and HPT2 were done by using a 15 ton hydraulic press and a 13 mm evacuable pellet-die system (SPECAC,