Journal of Food Engineering 128 (2014) 53–59

Contents lists available at ScienceDirect

Journal of Food Engineering

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

# Effects of high-pressure homogenization on thermal and electrical properties of wheat starch

Shuang Qiu [a], Yuanyuan Li [b], Hao Chen [a], Yan Liu [a], Lijun Yin [a,c,*]

[a] College of Food Science and Nutritional Engineering, China Agricultural University, P.O. Box 40, No. 17 Qinghuadonglu, Haidian, Beijing 100083, PR China
[b] Wuhan Botanical Garden, Chinese Academy of Sciences, Moshan, Wuchang, Wuhan 430074, PR China
[c] College of Food Science and Technology, Henan University of Technology, No. 140 Shongshannanlu, Zhengzhou, Henan 450052, PR China

ARTICLE INFO

*Article history:*
Received 8 April 2013
Received in revised form 25 November 2013
Accepted 12 December 2013
Available online 25 December 2013

*Keywords:*
Wheat starch
Homogenization
Gelatinization
Electrical conductivity

ABSTRACT

To investigate the effects of high-pressure homogenization on wheat starch granules, soft wheat starch suspensions (5.0%) were homogenized at increasing pressures, ranging from 0 to 100 MPa. The structural and thermal properties of the treated starches were determined by microscopy, particle size distribution, differential scanning calorimetry, and damaged starch measurements. A laboratory-scale ohmic heating setup was used to heat homogenized starch–KCl suspensions and measure the electrical characteristics. The wheat starch was partly gelatinized after high-pressure homogenization, and the degree of gelatinization increased to 25.96 ± 1.0% when the homogenization pressure was 100 MPa. The electrical conductivities of the treated starch–KCl suspensions increased linearly with increasing temperature during ohmic heating. The slopes of the electrical conductivity–temperature curves of the homogenized starch suspensions during ohmic heating correlated with the degree of starch gelatinization.



## 1. Introduction

Starch is one of the most abundant natural resources and is widely used in the paper, textile, adhesive, and food industries (Hoover, 2001). Starch gelatinization has been studied because of its importance in the food industry. It has been well documented that high hydrostatic pressure (HHP) treatment, as an alternative to traditional heat treatment, results in gelatinization of starch suspensions at room temperature (Blaszczak et al., 2007; Kawai et al., 2007; Stute et al., 1996). Unlike the mechanism of heat-induced gelatinization, the starch granules gelatinized by HHP contain two different zones: an outer zone, which remains unchanged, and an inner zone, which is completely destroyed and forms gel-like structures (Blaszczak et al., 2007). However, some other physical properties of HHP and heat-induced starch gelatinization are alike. For example, Bauer and Knorr (2004) reported that with increasing pressure to 600 MPa, the degree of starch gelatinization increased, resulting in a gelatinization curve similar to that of thermal gelatinization. Vallons and Arendt (2009) also found that there were no significant differences between the rheological and microstructural properties of HHP-treated starches and heat-treated starches, in terms of gelatinization intervals.

Until now, because the time required for HHP treatment of starch is long and its operating costs are high, it has not been economically viable to use this process in the starch industry. On the other hand, dynamic high-pressure treatment is commonly used to homogenize a mixture at very short time so that it is same throughout, and it is popular in pharmaceutical, food, and biotechnology industries (Pandolf and Kinney, 1998). Although high-pressure homogenization technology has rarely been studied in isolated native starch processing, starch is a frequently used material in many industries and it is important to obtain more detailed knowledge of homogenization effects on the physical properties of starches. Che et al. (2007) found that the crystalline structure of cassava starch granules was very resistant to high-pressure homogenization at pressures up to 100 MPa. According to Wang et al. (2008), the X-ray diffraction pattern showed a loss of the crystalline structure of maize starch after homogenization treatment at 140 MPa. Differential scanning calorimetry (DSC) analysis of high-pressure-homogenized maize starch showed a distinct decrease in the onset and peak gelatinization temperatures ($T_o$ and $T_p$) and gelatinization enthalpy ($\Delta H_{gel}$) with increasing homogenization pressure.

Ohmic heating, also known as Joule heating and resistive heating, is the process by which the passage of an electric current releases heat through a conductor. Ohmic heating is recognized as a rapid, effective, and homogeneous heating method, and it shows considerable potential use in food processing (Sastry and Salengke, 1998). Wang and Sastry (1997) developed a method for the

* Corresponding author. Address: P.O. Box 40, No. 17 Qinghua East Road, Haidian, Beijing 100083, PR China. Tel./fax: +86 10 62737424.
*E-mail address:* ljyin@cau.edu.cn (L. Yin).

0260-8774/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jfoodeng.2013.12.011

determination of the starch gelatinization temperature and the degree of gelatinization using ohmic heating. Li et al. (2004) found that during ohmic heating, the swelling of starch granules during gelatinization caused a decrease in the electrical conductivity ($\sigma$) of the starch suspensions, and the shape of the $d\sigma/dT$ versus $T$ curve was essentially the same as that of the DSC thermogram. The ohmic heating method could provide an alternative method to DSC, with the potential for rapid online measurement of starch gelatinization temperatures (Wong et al., 2011; Morales-Sanchez et al., 2009). Electrical conductivity has also been used as a novel tool for the determination of HHP-induced starch gelatinization (Bauer and Knorr, 2004). However, the relationship between electrical conductivity and high-pressure homogenization of treated starch has not been reported before.

Generally, wheat starch is studied because of its global use as a food material, and because it is an A-type starch, which is less pressure-resistant than other starches (Stute et al., 1996; Bauer and Knorr, 2005). In the present work, a wheat starch suspension was homogenized and then ohmically heated. The effects of high-pressure homogenization on the structural, thermal, and electrical characteristics of the wheat starch were investigated using microscopy, damaged starch determination, DSC. The electrical conductivity of the ohmic heating was analyzed in order to broaden the application of electrical conductivity in estimating starch properties.

## 2. Materials and methods

### 2.1. Materials

Soft wheat starch was purchased from Beijing Haoshihui Food Co., Ltd., China. An electronic moisture analyzer (MA150, Sartorius AG, Germany) was used to determine the moisture content of the starch, and the average value was determined to be 8.37% (w/w). The protein content of the starch was 0.35%, and was measured according to AACC 46-13, 2000. The ash content was quantified using an SM-98-10 oven (Tianjin Huabei Instruments, China); the average value was 0.18%. Suspensions containing 5% (w/w) starch were prepared by mixing with KCl solution (0.05 M) at room temperature (about 25 °C) for the homogenization and ohmic heating procedures.

### 2.2. High-pressure homogenization of starch suspension

Starch–KCl slurries were homogenized using a laboratory-scale high-pressure homogenizer (NS1001L-PANDA 2K, NiroSoavi S.p.A., Parma, Italy) at each of 0, 40, 60, 80, and 100 MPa for one pass. Approximately 150 mL of starch–KCl suspension were obtained at each pressure level. The NS1001L 2K homogenizer was a two-stage homogenizer with two high-pressure valves. The pressure of the second valve was adjusted to about 1/10 of the pressure in the first high-pressure stage (Che et al., 2007).

After the high-pressure treatment, the homogenized starches were incubation at 20 °C for 30 min using deionized water. Some of the samples were vacuum-filtered and dried with a laboratory-scale vacuum freeze dryer (LGJ-18, Beijing Sihuan Corporation, China) to obtain dry starch samples (Shi et al., 2012). The remaining dried starch samples were stored in a desiccator for later studies.

### 2.3. Microscopy of homogenized starch suspensions

The homogenized suspensions were directly observed under an optical microscope (B203 Biological Microscope, Chongqing Optec Instrument Co., Ltd., China). The microscope was equipped with a charge-coupled device camera module to present images.

### 2.4. Particle size analysis

The mean particle size of the starch suspension was measured using a laser diffraction particle size analyzer with a lowest measuring limit of 40 nm (LS 320, Beckman Coulter, Inc., FL, USA).

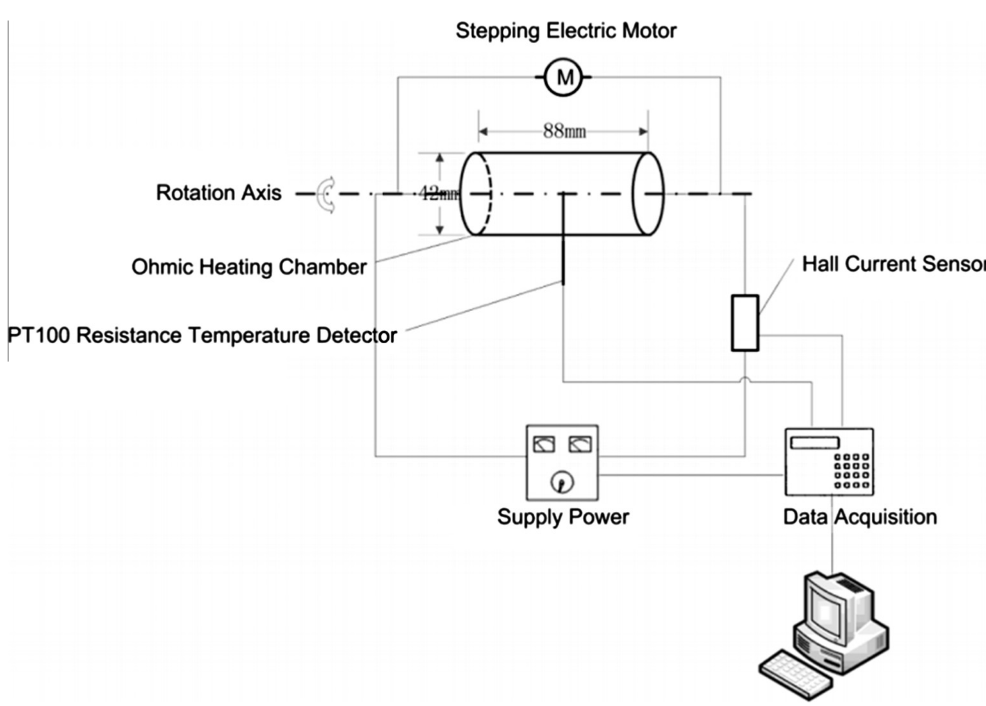


**Fig. 1.** Ohmic heating setup for electrical conductivity and temperature measurement (Wong et al., 2011).