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Physicochemical characteristics of high pressure gelatinized mung bean starch during recrystallization

Wenhao Li[a], Hongmei Guo[a], Peng Wang[a], Xiaoling Tian[a], Wei Zhang[a], Ahmed S.M. Saleh[b], Jianmei Zheng[a], Shaohui Ouyang[a], Qingui Luo[a], Guoquan Zhang[a,*]

[a] College of Food Science and Engineering, Northwest A&F University, Yangling 712100, China
[b] Department of Food Science and Technology, Faculty of Agriculture, Assiut University, Assiut 71526, Egypt

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ABSTRACT

The changes in physicochemical and structural properties of Ultra high pressure (UHP) gelatinized mung bean starch were investigated during 0 to 196 h retrogradation process by using X-ray diffraction (XRD) and differential scanning calorimetry (DSC). XRD analysis showed that the UHP-gelatinizated granules regenerated its original C-type crystallinity structures after retrogradation. The swelling power and solubility of native starch were increased with the increase in the assay temperatures from 50 to 90 °C, while the changing trend of the retrogradated granules was more gradual over entire assay temperatures. In addition, retrogradated granules showed a progressive decrease in the light transmittance and an increase in the amount of resistant starch as the ageing time increased from 0 to 192 h. DSC analysis suggested a slight increase in the transition temperatures (T_o, T_p and T_c) and the retrogradation enthalpy as the storage time increased. In contrast no endothermic transition peak could be observed using DSC after storage of heat-gelatinized mung bean starch gel.

1. Introduction

Mung bean (*Phaseolus radiatus*) is native to China and has been mainly grown in Asian countries and is also widely cultivated in Africa, South and North America, and Australia (Han, Yang, & Ma, 2010; Kaur, Sandhu, Singh, & Lim, 2011). Starch is the dominating component of mung bean, which constitutes about 54.73% to 57.99% of the composition of whole-seed with amylose content of 40.44% to 41.82% of the total starch amount (Li, Shu, Zhang, & Shen, 2011a). Mung bean starch has been regarded as the best raw material for starch noodle processing because of its high amylose content and the molecular structure of the amylopectin (Hoover, Li, Hynes, & Senanayake, 1997; Kasemsuwan, Bailey, & Jane, 1998; Li et al., 2011a). Mung bean starch noodle become soft, slippery, and have a high tensile strength when they are soaked in hot water.

In addition to noodles, mung bean sheets, are also available. A jelly product is called liangfen, which made of mung bean starch, is very popular food in China during summer, while, a similar jelly product colored yellow with the addition of gardenia coloring, called nokdumuk, is made in Korea. Although a great number of mung bean starch based foods with different functionalities and specialties are available in the market, mung bean starch has not been extensively utilized for food or non-food industrial applications when compared with many other starches. A major factor, which has an adverse effect on the utilization of mung bean starch in industry, is its high extent of retrogradation due to the high content of amylose (Li et al., 2011a).

Due to the increasing demand for starches with specific properties, there is a need for new strategies and technologies to modify native starch to meet the special needs and promote the utilization of starch in food industry applications. Several modification methods have been used to change the properties of mung bean starch, such as annealing (Chung, Moon, & Chun, 2000; Yoon & Kim, 2003), heat–moisture treatment (Li, Ward, & Gao, 2011b), oxidation and esterification (Bushra et al., 2013a), and microwave assisted acetylation (Bushra, Xu, & Pan, 2013b). However, these technologies have not been applied in mung bean starch until now.

Ultra high pressure (UHP) has attracted growing interest in the food processing industry in recent years. When a starch suspension is treated with UHP, water molecules could penetrate from amorphous into crystalline regions within starch granules under pressure, without any assistance of additional thermal treatment

* Corresponding author at: Northwest A&F University, College of Food Science and Engineering, Xi Nong lu 28 no., Yangling 712100, China. Tel.: +86 02987092171; fax: +86 02987092171.
E-mail address: zhanggq98@nwsuaf.edu.cn (G. Zhang).

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(Błaszczaka, Fornala, Valverdeb, & Garridoc 2005; Knorr, Heinz, & Buckow, 2006). Thus, starch gelatinization can be induced at room temperature after UHP treatment. Therefore, UHP technology can induce gelatinization and other physical modification of starch granules. It is recognized that UHP gelatinized starch shows different properties from heat-gelatinized one (Blaszczak, Valverde, & Fornal, 2005; Buckow, Heinz, & Knorr, 2007; Fukami, Kawai, Hatta, Taniguchi, & Yamamoto, 2010; Li et al., 2010, 2011a; Kim, Kim, & Baik, 2012).

Although there is a large number of literature describing the effects of UHP on gelatinization characteristics, physicochemical properties, structural properties and rheological properties of varying kinds of starches (Błaszczaka et al., 2005; Blaszczak et al., 2005; Knorr et al., 2006; Buckow et al., 2007; Oh, Hemar, Anema, Wong, & Pinder, 2008; Fukami et al., 2010; Li et al., 2010, 2011a), the number of studies carried on the retrogradation properties of the high pressure gelatinized starch are limited. A previous study has reported that the retrogradation rate of normal rice starch (Doona, Feeherry, & Baik, 2006) and wheat starch (Hu et al., 2011) gelatinized by UHP was slower than the heat-gelatinized one. Furthermore, the retrogradation extent of UHP-gelatinized corn and wheat starches depended on the storage temperature and starch type (King & Kaletunc, 2009).

In our previous study, we have investigated the effect of UHP on physicochemical and structural properties of mung bean starch. UHP treatment at 600 MPa could lead to a completely gelatinization of mung bean starch (Li et al., 2010). However, the changes in physicochemical and structural properties of high pressure gelatinized mung bean starch during its retrogradation process have not been studied. Therefore, the aim of this study was to evaluate the retrogradation properties of mung bean starch gelatinized by UHP and explore the retrogradation mechanism for UHP-induced starch gelatinization.

2. Materials and methods

2.1. Materials

Mung bean starch was purchased from Fuqiao Starch Co., LTD, Hengshui, Hebei province, China. All of the chemical reagents used in this study were of analytical grade.

2.2. High pressure and heat treatment gelatinization

Mung bean starch suspensions were prepared by mixing of starch with distilled water to concentrate of 30% (w/w, on a dry matter basis) and vacuum sealed in 200 mL polyethylene bags. The UHP treatment of starch–water suspensions was performed using a high pressure device (L2-600/0.6, Tianjin Huatai Senmiao Biotechnology Co., Ltd., Tianjin, China). The polyethylene bags were put into the high pressure chamber (with a capacity of approximately 2 L) and filled with water as the pressure transmitting medium. The samples were pressure-treated at the levels of 300, 450, and 600 MPa for 15 min at a pressure rise rate of approximately 350 MPa/min. After the pressure treatment, pressure was released automatically to atmospheric pressure, with a rate of pressure decrease of about 400 MPa/min. Then the samples treated at 300 and 450 MPa were broken into smaller pieces, vacuum-filtered and then freeze-dried to obtain dry starch samples. Meanwhile, the 600 MPa pressured starches gels were stored at room temperature for 0, 3, 6, 12, 24, 48, 96 and 192 h to perform the aging study. For heat treatment, the starch suspension was heated in a boiling bath water for 30 min with constantly stirring. Then all the treated samples were immediately cooled in water at 20 °C for 1 h before the following measurements. After each storage time, starch gels were freeze-dried and ground with a laboratory-scale grinder (FW100, Tianjin Test Instrument Co., Ltd., Tianjin, China). The retrograded starch samples were passed through a 100 mesh sieve and stored in an airtight container at room temperature for further analysis.

2.3. Microscopy observation

2.3.1. Scanning electron microscopy

Scanning electron microscopy (SEM) micrographs were taken using a scanning electron microscope (JSM-6360LV, JEOL, Japan). A starch sample was adhered on a SEM stub using double sided adhesive conductive tape and coated with a thin layer of gold to make the sample conductive. The mounted sample was then placed on the SEM stage and images were digitally captured at the accelerating voltage of 10 kV.

2.3.2. Light microscopy

Starch sample was suspended in a 1:1 glycerol solution (glycerol/H_2O, V/V) and was observed using a light microscopy (DMBA400, Motic China Group Co., Ltd, Guangzhou, China) with polarized light filter at 40-times magnification.

2.4. Determination of thermal properties

Thermal properties were performed according to our previous method (Li et al., 2014) by using a differential scanning calorimeter (DSC Q2000; TA Instruments, New Castle, USA) under ultra-high-purity nitrogen atmosphere. 3 mg (dry base, db) of each starch sample was directly measured into the aluminum pan and 12 μL of distilled water was added with a microsyringe, and an empty pan was used as reference for all measurements. The scanning temperature and the heating rates were 30–120 °C and 10 °C/min, respectively.

2.5. X-ray diffraction analysis

X-ray powder diffraction patterns were determined by using an X-ray diffractometer (XRD, Rigaku d/max2200pc, Rigaku Corporation, Tokyo, Japan) under the following conditions: radiation source, Cu*K*a (40 kV, 50 mA); angle of diffraction scanned from 5 to 60°; step size, 0.02; step time, 2 s. Before XRD analysis, the starch samples were ground to powders and equilibrated in a 100% relative humidity chamber for 48 h at room temperature to avoid the influence of relative humidity on relative crystallinity.

2.6. Determination of light transmittance and resistant starch content

Light transmittance of starch solution was conducted according to the method of Craig, Maningat, Seib, and Hoseney (1989). Resistant starch (RS) content measurement was performed using the Megazyme Resistant Starch Assay Kit (Megazyme Int. Ireland Ltd. Co., Wicklow, Ireland).

2.7. Determination of swelling power and solubility

Swelling power and solubility were determined at 50 °C, 60 °C, 70 °C, 80 °C, and 90 °C, respectively, according to the method of Leach, McCowen, and Schoch (1956).

2.8. Statistical analysis

All the experiments were performed in triplicate. Results were analyzed using Analysis of Variance (ANOVA), and expressed as mean value ± standard deviation. A Duncan's multiple range test