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Effect of thermal processing on the physicochemical properties of chestnut starch and textural profile of chestnut kernel

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ABSTRACT

The present study focused on the effect of thermal processing on the physicochemical properties of chestnut starch and textural profile of chestnut kernel. After thermal processing, the total starch content in both boiled and roasted chestnuts decreased significantly ($P < 0.05$), while the amylose content of boiled chestnut increased and that of roasted chestnut remained stable. The granular microstructure of the starch in cooked chestnut was gradually destroyed during the thermal processing. The starch in cooked chestnut still exhibited C-type X-ray diffraction patterns, but the intensity of diffraction peaks and the crystallinity were obviously declined compared with those of fresh chestnut. Textural profile analysis of chestnut starch gel and chestnut kernel showed that the main textural characterizations of roasted chestnut were higher than those of boiled chestnuts. These results are helpful for better understanding the texture change in fresh, boiled and roasted chestnuts, which indicated that roasting is an alternative industrial thermal processing method for chestnut kernel.

1. Introduction

The chestnut (*Castanea mollissima* Blume), which originated in China and has a long growing history of over 3000 years, is an important edible fruit and economic food resource in China and makes a large contribution to the national economy (Borges, Carvalho, Correia, & Silva, 2007). Chestnut fruit is considered a high nutritional value food and has a unique taste and flavor; it is consumed widely throughout America, Europe and Asia (Liu, Wang, Chang, & Wang, 2015). Studies suggest that the chestnut is an excellent source of essential fatty acids and minerals (K, P, and Mg), vitamins, dietary fiber and amino acids (Yang, Jiang, Gu, Yang, & Jiang, 2010).

The traditional cooking method for Chinese chestnut is frying unshelled. Currently, a type of packaged boiled chestnut kernel has been industrially processed and has become popular in East and Southeast Asia. Thermal processing is an important physical method that uses simple and environmentally safe technologies at a low cost with the production of few chemical reagent by-products (Zavareze, Storck, Castro, Schirmer, & Dias, 2010). After treatment by home cooking or industrial processing, the nutrition, taste, and shelf-life of chestnut fruit were changed. A previous study was performed that investigated the effects of different cooking treatments on the nutritional composition of chestnut fruits. It revealed that chestnut fruits lost approximately 25% of their energetic value and gained humidity after boiling, while the energy level increased significantly by roasting and the available sugars increased by 25% (De Vasconcelos, Bennett, Rosa, & Ferreira-Cardoso, 2010a). A recent study showed that the contents of protein and insoluble and total dietary fiber increased after roasting, while there was a decrease in protein content and an increase in fat content in boiled chestnut fruit (Gonçalves et al., 2010). Industrial processing methods have both positive and negative effects on chestnut nutrients. The positive effects include increases in neutral detergent fiber and total phenolics after freezing, and the negative effects include reductions in the levels of total starch, ascorbic acid and fat (De Vasconcelos, Bennett, Rosa, & Ferreira-Cardoso, 2009a; De Vasconcelos, Bennett, Rosa, & Ferreira-Cardoso, 2009b; De Vasconcelos, Bennett, Rosa, & Ferreira-Cardoso, 2010b).

Chestnut fruit is a good source of starch as it has a content between 38%–80% (Borges, Gonçalves, de Carvalho, Correia, & Silva, 2008). After processing, starch chains are decomposed, and the textural properties such as pasting, aging and gelatinization are altered

Abbreviations: FC, fresh chestnut; BC, boiled chestnut; RC, roasted chestnut; FCSG, fresh chestnut starch gel; BCSG, boiled chestnut starch gel; RCSG, roasted chestnut starch gel; TPA, textural profile analysis.

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by different processing methods (Panda, Pal, Bal, & Mohapatra, 2015). For example, the X-ray diffraction pattern of potato starches was shifted from B- to A-type after thermal processing (Vermeylen, Goderis, & Delcour, 2006). Moreover, the crystallinity of the starch decreased after thermal processing, while the viscosity profiles also changed significantly. The treated starches had a higher pasting temperature and lower viscosity (Jiranuntakul, Puttanlek, Rungsrdthong, Puncha-arnon, & Uttapap, 2011). At present, the structural and functional properties of fresh chestnut starches have been well studied (Liu et al., 2015), and the effect of drying method on rheological, thermal, and structural properties of chestnut flour was also evaluated (Ahmed & Al-Attar, 2015; Correia & Beirão-da-Costa, 2012a; Moreira, Chenlo, Torres, & Rama, 2013). However, there are few comparative studies on the effect of different thermal processing methods on the physicochemical properties of chestnut starch. Knowledge about the physicochemical properties of chestnut starch after thermal processing appears particularly important because starch is the main constituent of chestnut fruit and is crucial to the texture of chestnut products.

The home-made fried or roasted chestnuts exhibited different sensorial qualities, i.e., color, taste, aroma and textural profiles, from the industrially boiled packaged chestnut kernels. In our previous study, the effect of cooking methods on nutritional quality and volatile compounds of Chinese chestnut has been investigated (Li et al., 2016). Therefore, the aim of the present study was to focus on the effect of different thermal processing methods on chestnut fruits by comparing the physicochemical properties of chestnut starch and textural profile of fresh, roasted and boiled chestnut kernels, in order to provide an alternative method for the industrial processing of chestnut kernel.

2. Materials and methods

2.1. Raw materials and sample preparation

Chestnut fruits were collected from Qianxi, Hebei Province of China. The samples were thermally processed with different methods at various degrees of cooking and divided into the following groups: (A) fresh chestnut (FC); (B) boiling process in an autoclave (SYQ-DSX-280A, Shenan Medical Devices Co., Ltd., Shanghai, China) at 121 °C for 6, 10, 16, and 20 min, which represented cooking degrees of 30%, 50%, 80%, and 100%, respectively, and were recorded as BC-I, BC-II, BC-III, and BC-IV, respectively; (C) roasting process in an oven (T3-L383b, Guangdong Midea Kitchen Appliance Manufacturing Co. Ltd., China) at 200 °C for 6, 10, 16, and 20 min, which represented cooking degrees of 30%, 50%, 80%, and 100%, respectively, and were recorded as RC-I, RC-II, RC-III, and RC-IV, respectively. The cooking degree was roughly estimated as the ratio of cooked/total area of the cross-section. The samples were unshelled and cut, and the cross sections were shown in Fig. 1.

2.2. Analysis of total starch and moisture content in chestnut kernel

Total starch content in chestnut kernel was determined according to the AOAC method 996.11 (AOAC, 1997). Fresh and cooked chestnuts were hulled; the kernels were chopped, lyophilized, and ground to a powder of 40-mesh, then 100 mg of powder was washed with aqueous ethanol and pre-treated with dimethyl-sulphoxide at 100 °C to disperse starch before analysis. The samples were incubated with α-amylase and amyloglucosidase to hydrolyze starch in sodium acetate buffer (200 mM, pH 4.5) at 50 °C for 30 min. The concentration of glucose was determined by spectrophotometric measurement at 510 nm and the total starch content was calculated by Eq. (1):

$$Totalstarch(\%) = A \times \frac{F}{W} \times 90 \quad (1)$$

where A is the absorbance of reaction solutions read against reagent blank; F is 100 μg glucose/absorbance value for 100 μg glucose; W is the weight of starch power (mg).

The water content of chestnut kernel was measured after oven (GZX-9140MBE, Boxun Medical Devices Co., Ltd., Shanghai, China) drying at 105 °C until a constant weight was reached (AOAC method 925.40) (AOAC, 1997).

2.3. Extraction of chestnut starch

Starch was isolated by alkaline methods according to a procedure described by Liu et al. (2015) with some modifications. Approximately 500 g of chestnut kernel was chopped into small pieces and immersed in 1000 mL of NaOH solution (0.2%, w/v) for 2 h at 4 °C. Subsequently, the mixture was homogenized and filtered through a 75 μm stainless sieve to remove large particles. The filtrate was centrifuged at 4000*g* for 5 min, and then the mucilaginous layer was scraped away, and the precipitate was washed three times with distilled water. The extracted starches were lyophilized (at −40 °C for 48 h with the vacuum degree of 0.01 MPa) and ground to 40-mesh again. The starch extraction yield in each experiment was expressed as: g starch/100 g flour (both on dry basis) (Correia & Beirão-da-Costa, 2012b). The amylose content was analyzed using the K-AMYL 07/11 Amylose/Amylopectin assay kit (Megazyme International Ireland, Ireland). Chestnut starch samples were completely dispersed by heating in dimethyl sulfoxide (DMSO) (Maršálková et al., 2010; https://secure.megazyme.com/Amylose-Amylopectin-Assay-Kit).

2.4. Microstructure of chestnut starch granules

Chestnut starch granules were imaged using the S-3400 N Scanning Electron Microscope (Hitachi, Japan). The samples were mounted on studs and sputter coated with gold. An accelerating voltage of 5 kV was used during scanning.

2.5. Analysis of the crystal properties of chestnut starch

X-ray diffraction analysis was performed using an X-ray diffractometer (D8 Discover, Bruker Corporation, Germany) operating at 40 kV and 40 mA. The intensity was set from 5 to 45° as a function of 2θ and at a scanning speed of 2°/min and a step size of 0.02° (Wang, Pan, Hu, Miao, & Xu, 2010). The crystallinity was quantitatively estimated as a ratio of the crystalline area to the total area using MDI JADE 6.5 software (Materials Data Inc., Livermore, CA, USA) using the following equation:

$$\text{Crystallinity}\,(\%) = (\text{area under peaks}/\text{total area}) \times 100$$

2.6. Thermal properties of chestnut starch

The thermal properties of starches were measured using a Differential Scanning Calorimeter (DSC 200F3, Netzsch, Germany) equipped with a thermal analysis data station. An empty pan was used as a reference. The pans were heated from 20 to 115 °C at a scanning rate of 10 °C/min. The transition temperatures reported were the onset (T_O), peak (T_P) and conclusion (T_C) of the gelatinization endotherm. ΔH represents the required energy for disrupting hydrogen bonds within the crystalline zones (Sun, Gong, Li, & Xiong, 2014).