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Changes in physicochemical properties related to the texture of lotus rhizomes subjected to heat blanching and calcium immersion

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ABSTRACT

Pretreatments such as low temperature blanching and/or calcium soaking affect the cooked texture of vegetal food. In the work, lotus rhizomes (*Nelumbo nucifera* Gaertn.) were pretreated using the following 4 treatments, blanching at 40 °C, blanching at 90 °C, soaking in 0.5% $CaCl_2$, and blanching at 40 °C followed by immersion in 0.5% $CaCl_2$. Subsequently, the cell wall material of pretreated samples was isolated and fractioned to identify changes in the degree of esterification (DE) and monosaccharide content of each section, and the texture of the lotus rhizomes in different pre-treatments was determined after thermal processing with different time. The results showed that the greatest hardness was obtained after blanching at 40 °C in $CaCl_2$, possibly attributing to the formation of a pectate calcium network, which maintains the integrity of cell walls. Furthermore, the content of galactose, rhamnose and arabinose decreased due to the breakage of sugar backbones and subsequent damage to cell walls. Our results may provide a reference for lotus rhizome processing.

1. Introduction

Lotus rhizomes (*Nelumbo nucifera* Gaertn.) are an aquatic perennial plant of economic importance and are widely cultivated in China, India and Eastern Asia for food, ornamental and medicinal purposes (Hu et al., 2011; Man et al., 2012; Shad, Nawaz, Hussain, & Yousuf, 2011). Hubei province, China constitutes approximately 50% of the lotus rhizome cultivation area and production value in China. Several characteristics of lotus rhizomes have been reported, including starch properties (Zhong, Chen, & We, 2007) and anti-oxidant (Ling, Xie, & Yang, 2005), anti-viral (Kuo, Lin, Liu, & Tsai, 2005) and anti-obesity (Ono, Hattori, Fukaya, Imai, & Ohizumi, 2006) effects. However, little information on its physicochemical changes such as texture quality under different pre-treatment conditions is available.

Pectin is a polysaccharide in primary cell walls and middle lamellae and consists of D-galacturonic acids linked by α-1, 4 glycosidic linkages to form a linear backbone, to which neutral sugar side chains are attached (Liu et al., 2010). Galacturonic acid (GalA) residues can be methylesterified, depending on the degree of esterification (DE). Furthermore, textural properties such as hardness are often used as an indicator of consumption quality (Zheng, Zhang, Song, Lin, & Kan, 2013). In the absence of polygalacturonase (PG) activity, intensive de-esterification of pectin by pectin methylesterase (PME) occurs throughout the entire cell wall, which can enhance textural characteristics, because free pectic carboxyl groups can cross-link with divalent ions (Christiaens et al., 2012). In addition, Ca^{2+} loss from the pectin-rich middle lamella enhances the softness of the fruit. Accordingly, treating fruit with Ca^{2+} usually results in firmer fruit than non-treated controls (Jaworska & Bernas, 2010). Brummell (2006) has noted that the action of a large number of cell wall-localized proteins are responsible for such comprehensive modifications, causing solubilization and depolymerization, which ultimately affect cell wall strength and lead to fruit softening. Calcium applications, especially treatment with high Ca^{2+} concentrations, may help maintain the textural properties of dried papaya (Udomkun, Mahayothee, Nagle, & Müller, 2014). In addition, Chinese water chestnut failed to soften during

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cooking due to the thermal stability of cell wall polymers involved in cell-cell adhesion and the monosaccharide composition of various fractions (Parker & Waldron, 1995). Despite the aforementioned studies, the texture of lotus rhizomes is rarely discussed in the literature, particularly texture softening during traditional cooking.

To evaluate the effects of different pre-treatment conditions on the texture of lotus rhizomes after cooking, we investigated the physicochemical properties of lotus rhizomes including cell wall material, galacturonic acid content, degree of esterification, and monosaccharide composition. Samples were subjected to various pre-treatment conditions, including high-temperature blanching (90 °C), low-temperature blanching (40 °C), and immersion in 0.5% calcium chloride solution (to cross-link pectic polymers with Ca^{2+}), as well as low-temperature blanching combined with $CaCl_2$ immersion.

2. Materials and methods

2.1. Materials and samples preparation

Freshly harvested lotus rhizomes (Hubei lotus No. 8 cultivar, harvested in December, 2012) were obtained from Wuhan Vegetable Research Institute. The samples were selected for size uniformity, quality and lack of mechanical damage, and then washed with tap water to remove mud and were sliced into 1-cm thick segments for hardness tests. Other parts were ground into powders with a particle size of ca. 80 mesh after freeze drying and were stored at −20 °C until further use.

Our preliminary experiments (Xie, Du, Li, Wang, & Yan, 2013) showed that the maximum conditions for the inactivation of PME were 40 °C for 30 min and 90 °C for 10 min, respectively, combined with 0.5% calcium chloride immersion. We designed the 5 types of pre-treatments as follows:

(a) Without any pretreatment, control (CK).
(b) Blanching at 40 °C for 30 min (40 °C).
(c) Blanching at 90 °C for 10 min (90 °C).
(d) Immersion in $CaCl_2$ for 1 h (Ca).
(e) Blanching at 40 °C for 30 min combined with immersion for 1 h (40 °C + Ca).

After each pre-treatment, samples were cooked in boiling deionized water for up to 80 min, and then the samples with different cooking time were cooled to room temperature before texture measurements.

2.2. Hardness analysis

Our well-defined instrumental method can be described as follows: metering mode: texture profile analysis (TPA); probe: P6; plotting parameters: 1.00 mm/s; testing speed: 1.00 mm/s; post-test speed: 1.00 mm/s; compression ratio: 30%; time between two compressions: 2 s; According Fig. 1 the lotus rhizome was cross cut into discs, and then the discs were pretreated before cooking, each measurement was performed nine times, and the average was obtained. Hardness was defined as the most vigorous during the first compression.

2.3. Extraction, fractionation and quantification of cell wall materials

Cell wall materials (CWM) were isolated as described by Nguema-Ona et al. (2012), with minor modifications. The CWM, extracted as alcohol insoluble residues (AIR), was fractionated into various pectin fractions. The first fraction was the water soluble

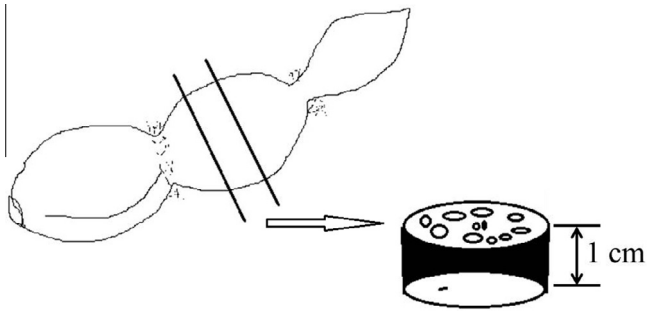

Fig. 1. Schematic diagram of slicing and sampling of lotus rhizome for TPA analysis.

fraction (WSF) and was obtained by incubating 250 mg of AIR in 45 mL of stirred boiling water (Sila, Smout, Elliot, Loey, & Hendrickx, 2006). After 5 min, the suspension was cooled to ambient temperature and was filtered. The pH of the filtrate was then adjusted to 6.5 and was diluted with water to 50 mL. The residue was re-suspended in 45 mL of 50 mmol/L cyclohexanetrans-1,2-diamine tetraacetic acid (CDTA) in 0.1 mol/L sodium acetate (pH 6.5) at 25 °C for 6 h and was filtered. After adjusting the filtrate volume to 50 mL, the chelator soluble fraction (CSF) was obtained. The residue was re-incubated in 45 mL of 50 mmol/L Na_2CO_3 containing 20 mmol/L $NaBH_4$ at 4 °C for 12 h and at 28 °C for 6 h. The mixture was filtered, and the volume of the filtrate was adjusted to 50 mL. This fraction is called the sodium carbonate soluble fraction (NSF) (Chin, Ali, & Lazan, 1999).

All cell wall materials were analyzed for their GalA content. The DE values of the WSF and CSF fractions were also determined, whereas the DE value of the NSF fraction could not be assayed due to the saponification step of methyl esterification during the alkali extraction of this fraction (Christiaens et al., 2012).

2.4. Determination of the galacturonic acid content

The GalA concentration was measured colorimetrically using 3,5-dimethylphenol on hydrolyzed CWM, according to the previous report of McFeeters and Lovdal (1987).

2.5. Determination of the degree of esterification

The DE was determined according to the method of Chatjigakis et al. (1998).

2.6. Determination of the monosaccharide composition

The monosaccharide composition was determined using a gas chromatography-mass (GC–MS) method with minor modifications (Varma, Varma, Allen, & Wardi, 1973). One tenth of a gram of pectin was hydrolyzed in 2 mL of 0.5 mol/L H_2SO_4 in a sealed test tube at 100 °C for 4 h and was neutralized to pH 6.5–7.0 with $BaCO_3$. The hydrolysate was filtered, freeze-dried, and dissolved in 0.5 mL of 0.02 (w/v)% pyridine-NH_2OH HCl in a sealed test tube at 90 °C for 30 min. The solution was cooled to ambient temperature and was acetylated with 0.5 mL of acetic anhydride at 90 °C for 30 min. After the alditol acetate derivatives of the neutral sugars were extracted once with dichloromethane, a 5-μL aliquot of the sample was injected into a HP 6890 gas chromatograph equipped with flame ionization detector (FID) (Agilent, USA). A HP-5 (30 m × 0.32 mm × 0.25 mm) capillary column was used to separate the neutral sugar derivatives with a split ratio of 30:1. Nitrogen gas was used as the carrier gas at a column flow rate of 10 mL min^{-1}. The temperature programme was set as follows: the initial column temperature of 150 °C was held for 1 min and