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Selective peroxidase inactivation of lightly milled rice by superheated steam

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ABSTRACT

Superheated steam (SS) was used to inactivate peroxidase of lightly milled rice (LMR) in this study in order to extend shelf-life of LMR. Meanwhile, the effects of SS on physicochemical properties of LMR were evaluated. Compared with hot air (HA), SS could inactivate peroxidase of LMR within a shorter time and result in lesser reduction of moisture content. SS caused much less fissures and alteration of micro-mechanical behavior (intercellular and intracellular cleavage) to LMR than HA did. SS-stabilized LMR, of which peroxidase was inactivated by SS, maintained their natural physicochemical properties including appearance (whiteness of uncooked rice and morphology of cooked rice), cooking quality (water absorption, volume expansion ratio and total solids loss), and texture profile (hardness, adhesiveness chewiness and cohesiveness). Physicochemical properties of LMR were closely connected with fissures. The morphology and texture of cooked LMR might be partly explained by the micro-mechanical behavior of uncooked LMR. SS would be a promising technology for inactivating peroxidase and retaining natural physicochemical properties of LMR simultaneously.

1. Introduction

Non-starch nutrients, such as minerals, vitamins and antioxidants are largely concentrated in the external bran layer of rice (Liang et al., 2008; Roberts, 1979; Thanonkaew et al., 2012). However, the entire bran layer, typically representing about 10% of brown rice by weight, is conventionally removed during commercial milling and polishing operations. The resultant well-milled rice is the primary rice products in markets. Now this processing mode sharply conflicts with people's growing concerns on health. Unmilled brown rice is nutritious, but it is difficult to cook due to the wrapping of an impermeable epidermal layer. A credible alternative to well-milled rice and unmilled brown rice is lightly milled rice (LMR), of which the outermost epidermal layer is partially removed by plasma (Chen et al., 2012), flour-blasting (Guraya, 2011), milling (Desikachar et al., 1965; Roberts, 1979) or other processes. Partial removal of the epidermal layer facilitates the penetration of water into the underlying endosperm, thus improving the inferior cooking parameters of brown rice (Chen et al., 2012; Desikachar et al., 1965; Guraya, 2011), as well as retaining most of the nutritious bran layer (Roy et al., 2008; Roberts, 1979).

However, physical injury induced by the above flour-blasting, milling treatment or other processes will break the natural barrier between lipids and lipolytic enzymes which are enriched in the bran layer, contributing to the accelerated hydrolytic rancidity and oxidative rancidity of LMR. Several reports have reported the shorter shelf life of LMR than well-milled rice and brown rice (Guraya and Patindol, 2011; Piggott et al., 1991; Zhong et al., 2013). In order to extend the shelf life of LMR, the lipolytic enzymes need to be inactivated. Heat treatments are often used to inactivate enzymes in food. However, common heat treatments usually alter the natural physicochemical properties of food. It remains a challenge to inactivate lipolytic enzymes of LMR while maintaining its natural physicochemical properties.

Superheated steam (SS) is steam, the temperature of which exceeds that of saturated steam at the same pressure. High temperature SS can be achieved at atmospheric pressure. Therefore, SS is safe and suitable for industrial production. From the viewpoint of product quality, the advantages of using SS as a heat medium has

Abbreviations: LMR, lightly milled rice; SS, superheated steam; HA, hot air; PN, peroxidase activity test was negative; SS110 (PN), SS120 (PN), HA110 (PN) and HA120 (PN), represented the LMR samples of which peroxidase was inactivated by 110 °C (or 120 °C) SS (or HA) in the shortest time; SEM, scanning electron microscopy.

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received increasing attention. Recently, SS has been found to be effective for suppressing lipid oxidation in canned pork bundles (Huang et al., 2004). The oat groats processed by SS have acceptable storage stability due to the inactivation of peroxidase (Head et al., 2011, 2010). Satou et al. (2010) suggested that SS treatment is enough to inactivate lipolytic enzymes in brown rice at a low temperature (above 125 °C) within a short time. However, little research has been conducted to investigate the effects of SS on physicochemical properties such as appearance (fissures, whiteness and translucency), cooking quality (optimum cooking time, water absorption, volume expansion ratio and total solids loss), texture profile (hardness, adhesiveness, chewiness and cohesiveness), and micro-mechanical behavior of LMR.

Peroxidase and lipolytic enzymes (lipase and lipoxygenase) are commercially important because they affect the keeping quality and shelf life of rice (Ramezanzadeh et al., 1999a, 1999b; Thanonkaew et al., 2012). Lipase is more stable than lipoxygenase in rice (Satou et al., 2010; Zhong et al., 2013), while peroxidases present higher heat-resistance than lipases (da Silva et al., 2006; Head et al., 2010). Accordingly, the peroxidase activity test was used for monitoring the adequate heating for stabilizing LMR in this study. Microwave irradiation was previously used to inactivate lipolytic enzymes of rice with different degrees of milling, but the treated rice was puffed (Zhong et al., 2013). In this study, we aimed to investigate whether SS treatment could simultaneously inactivate peroxidase and retain natural physicochemical properties of LMR. Hot air (HA) treatment was used as a reference.

2. Materials and methods

2.1. Materials

The paddy cv. Kongyu-131 was harvest in October, 2011 (Heilongjiang, China), and obtained from China Oil & Foodstuffs Corporation in April, 2012 (Jiangxi, China). Immediately after the paddy arrived, it was vacuum-packed and refrigerated at 4 °C until used. To obtain LMR, the paddy was dehusked with a rubber roll type husker (Model THU-35A, Satake, Japan) and milled to remove 3% by weight with a laboratory polisher (Model TM 05, Satake, Japan). Only intact LMR kernels (without any fissures) were selected for the subsequent experiments. Experiments were conducted immediately after the paddy arrived and finished in two weeks.

2.2. Superheated steam (SS) and hot air (HA) processing

The schematic of a laboratory scale SS and HA hyphenated apparatus is shown in Fig. 1. This apparatus was designed and manufactured by the food engineering center of Nanchang University. The major components of this apparatus are summarized in the caption of Fig. 1. The electric steam generator (12 kW), air compressor and four superheaters (0.5 kW) were used to generate SS and HA. The hot-air insulation chamber was used to create adiabatic conditions outside the processing chamber. To control the treatment temperature, a PID temperature controller was applied. Before the experiment, both the hot-air insulation chamber and the processing chamber were preheated to the test temperature. Untreated LMR grains (natural LMR) were scattered in a monolayer on the metal mesh of the sample tray for uniform heating. When the sample tray with LMR grains was inserted into the processing chamber, the computer began timing and recording. The velocity of flow of SS or HA was adjusted to 1.00 m/s. Treatment temperatures were 110 and 120 °C. Treatment time ranged from 0 to 10 min at 30 s intervals. Moisture content of untreated, SS treated and HA treated LMR was measured by a moisture analyzer (Model Hr83, Mettler toledo Inc., Switzerland).

2.3. Extraction and activity test of peroxidase

LMR samples, including untreated, SS treated and HA treated, were precooled in a freezer at −20 °C and then ground by an electric blender (Panasonic, model MX-795N, Japan). One gram rice flour (sieved through a 100-mesh screen) was added to 10 mL Mcllvaine's buffer (pH 5.0), and then the mixture was mixed for 10 min at 4 °C with a magnetic stirrer (ETS-D5, IKA, German). After that, the homogenate was centrifuged at 20,000 g for 30 min. The

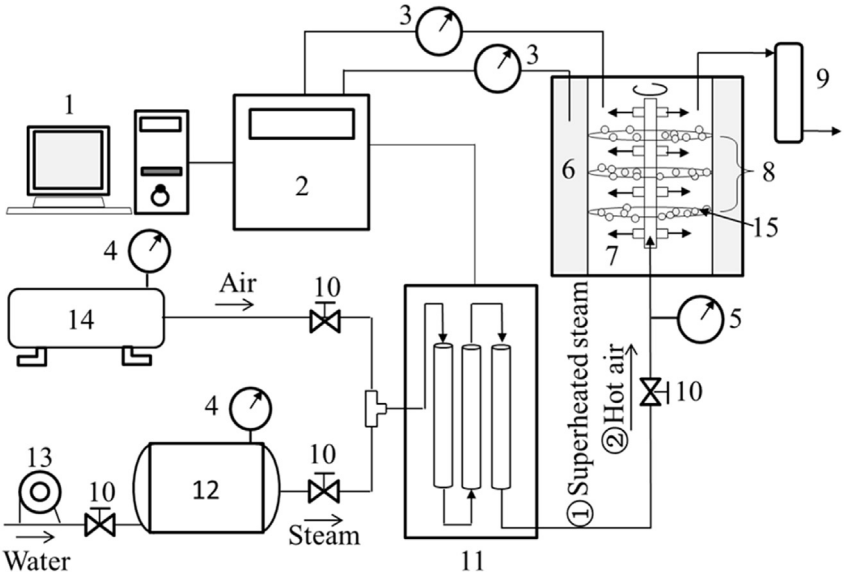

Fig. 1. Schematic of the superheated steam experimental apparatus: (1) personal computer; (2) PID temperature controller; (3) thermocouple thermometers; (4) gauge; (5) flowmeter; (6) insulated chamber equipped with electrical heater; (7) processing chamber; (8) sieve and rice grain placed in monolayer; (9) condenser; (10) valves; (11) parallel superheaters; (12) electric steam generator; (13) water pump; (14) air compressor; (15) LMR kernels.