LWT - Food Science and Technology 51 (2013) 196–204

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

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

Quick cooking rice by high hydrostatic pressure processing

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ARTICLE INFO

Article history:
Received 15 March 2012
Received in revised form
21 September 2012
Accepted 22 September 2012

Keywords:
Quick cooking rice
Jasmine rice
High hydrostatic pressure
Sensory quality
Texture

ABSTRACT

Jasmine rice was soaked for 0, 30, 45 and 60 min and then high hydrostatic pressure (HHP) processed, first at 300 and 400 MPa (for 2 and 4 min), and then a second HHP process was applied at 570 MPa for 20 min. The HHP-processed rice was heated in a microwave oven for 1.5 min, with a rice/water ratio of 1:2, and sensory evaluation and texture analysis were conducted. The quality of the pre-soaked rice and HHP-processed rice, before and after microwave heating, was obtained by measuring the degree of gelatinization with differential scanning calorimetry, and texture profile analysis. Also, the gelatinization and pasting properties of milled HHP-processed rice flour were determined using a Brabender Visco-amylograph. During soaking, the rice attained its highest moisture content (32.41 ± 0.43 %) in 30 min. It was shown that rice which was single HHP treated at 300 and 400 MPa had a better acceptance, in terms of grain shape, adhesiveness, cohesiveness and texture. In general, jasmine rice that had been HHP processed and then microwave heated for 1.5 min was more valued than jasmine rice just heated by microwave oven for 10 min, in terms of the grain shape, adhesiveness, cohesiveness, texture and overall quality.

1. Introduction

Worldwide, grains and legumes are the main source of dietary energy as well as a source of proteins and vitamins. As an example, rice is widely consumed as a staple food in Asia (Byun et al., 2010). Khao Dawk Mali (KDML) 105, which is commonly referred to as “jasmine rice”, is one of the most popular rice varieties in Thailand and is considered a vital crop for domestic consumption as well as a primary export commodity for Thailand’s economic growth (Leelayuthsoontorn & Thipayarat, 2006).

Although rice is not as popular in the USA and Europe as it is in Asia, a significant increase in the consumption of ready to eat (RTE) rice has been occurring, and markets in these regions are growing fast (Byun et al., 2010). The accelerated pace of modern life has promoted new ways to consume rice such as instant rice, also known as quick cooking rice (QCR), which is fully or partially cooked and dehydrated. QCR takes only a few minutes (less than 5 min) to prepare for consumption after rehydration (Wang et al., 2011).

Instant rice is still beset by problems including long rehydration time and inferior quality as compared to traditional cooked rice. The texture and physical appearance of cooked rice may vary depending on the method of cooking (Leelayuthsoontorn & Thipayarat, 2006). The texture of cooked rice is related to its amylose content and the fine structure of amylopectin. The intra- and/or inter-molecular interactions of starch with other components in rice such as proteins, lipids and non-starch polysaccharides affect the rice’s texture (Prasert & Suwannaporn, 2009).

Thermal processing has long been used as a common preservation technique in the food industry, which allows the stable and secure production of food. For RTE rice, thermal processing has provided good results in terms of sensory characteristics. However, in this case, there are losses in the nutritional quality of the product during processing and storage.

For more than two decades high hydrostatic pressure (HHP) has been investigated as an alternative to traditional thermal processing of foods (Hayashi, 1991, 1996). In addition to microbial and enzymatic inactivation, modifications of food proteins and starch by HHP treatment have received considerable attention (Kinefuchi, Sekiya, Yamazaki, & Yamamoto, 1999; Hayashi, 2002). HHP treatment has been demonstrated to result in conformational and functionality changes. Therefore, it is becoming possible to obtain products with the desired texture and with better sensory and nutritional attributes (Ahmed, Ramaswamy, Ayad, Alli, & Alvarez, 2007). By HHP processing, applied pressure is instantaneously and uniformly distributed within the product, therefore processing time is not influenced by sample

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0023-6438/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.lwt.2012.09.021

size. In addition, there are significant energy savings in comparison to thermal stabilization techniques, because once the desired pressure is reached, it can be maintained without the need for further energy input (Estrada-Girón, Swanson, & Barbosa-Cánovas, 2005).

In the case of cooked rice, the HHP process permits a homogeneous gelatinization and reduces the percentage of broken kernels (Prasert & Suwannaporn, 2009). Leelayuthsoontorn and Thipayarat (2006) showed the effects of pressurization on improving the properties of cooked rice, for example, its brightness, flavor and texture. Also, Yamakura et al. (2005) stated that HHP treatment of rice increased starch digestibility for all cultivars.

In addition, it has been demonstrated that the retrogradation rate of pressure-gelatinized starch was slower than that of heated starch. The lower retrogradation was attributed to existing intact starch granules and lower amylose leaching in the pressure-gelatinized starch (Hu et al., 2011).

On the other hand, it is known that rice presents an allergenicity problem; this problem is partly dependent on globulin and albumin fraction proteins. Urisu et al. (1991) found that a16 kDa protein and a 33 kDa protein were the major allergens. Recently, however, two globulin-like proteins, a 52 kDa protein and a 63 kDa protein, were identified as novel IgE-binding proteins that are candidates for rice allergens (Satoh, Nakamura, Komatsu, Oshima, & Teshima, 2011). This result was first reported in Japan in patients with a history of asthma induced by rice flour exposure and with eczema produced by rice ingestion (Kumar et al., 2007).

In this sense, some researchers (Li, Zhu, Zhou, & Peng, 2011) have ascertained that the allergenicity of rice and other food resources can be reduced by HHP processing. For example, Kato, Katayama, Matsubara, Omi, and Matsuda (2000) observed that a significant amount of allergenic proteins (mainly 16 kDa albumin and 33 kDa globulin) were eliminated in the pressure range of 300–400 MPa. The results obtained by Yamakura et al. (2005) suggest that rice protein was denatured by the HHP treatment (400 MPa, 10 min). In addition, HHP treatment can induce proteolysis to produce free amino acids, and gamma-aminobutyric acid (GABA) as a bio-function in brown rice can be increased by HHP treatment (Kinefuchi et al., 1999; Shigematsu et al., 2010). Thus, HHP treatment of rice could have considerable health benefits, in addition to facilitating certain functional and quality properties (Ahmed et al., 2007).

Thus, the preparation of QCR by HHP treatment is studied in this paper in order to improve the quality and appearance of the rice after cooking (brighter, without cracks and with a good texture), obtaining at the same time a healthier cooked rice without allergenic proteins and with less loss of functional compounds during cooking.

2. Materials and methods

2.1. Raw rice soaking

Golden Star® Brand jasmine raw rice (product of Thailand) from a supermarket (Pullman, Washington, USA) was soaked at a rice/water ratio of 1:5 and at 25 °C for 0, 30, 45, and 60 min and then was drained using a 5 μm mesh for 2 min. Samples with different soaking times were analyzed, obtaining moisture content, rice grain volume expansion, and texture (Lu, Siebernmorgen, & Archer, 1994).

2.2. HHP treatments

For each experiment, 20 g of rice grains and 100 mL of deionized water were packed in a polyethylene bag. This rice/water ratio provides enough water to complete gelatinization (Ahmed et al., 2007). The pack was sealed ensuring that the headspace in the pouch was kept to a minimum.

The pressure treatment was applied in a warm isostatic pressing system (Engineered Pressures Systems, Inc., Andover, Massachusetts, USA) with a cylindrical pressure chamber (ht. 0.25 m, dia. 0.10 m) and samples were subjected to pressure treatments of 300, 400, and 570 MPa at 25 °C for times of 2, 4, and 20 min. The samples were immersed in a high pressure vessel containing water as the hydrostatic fluid medium in the press. Then, different HHP treatments were carried out. Firstly, a single HHP treatment was done where rice that had been pre-soaked for 0, 30, 45, or 60 min was treated at 300 and 400 MPa for 2 and 4 min (Raso, Calderón, Góngora, Barbosa-Cánovas, & Swanson, 1998).

Secondly, a double HHP treatment was applied, consisting of a first HHP treatment at 300 and 400 MPa, followed by a further HHP treatment at 570 MPa for 20 min. The first HHP process was done in order to eliminate allergenic proteins and improve grain structure. The second process (at 570 MPa) was applied to achieve an appropriate degree of starch gelatinization.

After HHP processing, samples were filtered through a 5 μm mesh. Then, moisture content and texture were determined. Rice was heated in a microwave oven (Welbilt Model MR99T microwave oven, Welbilt Appliances, Inc., New Hyde Park, New York, USA) for 1.5 min on high power (850 W), with a rice/water ratio of 1:2; sensory evaluation and texture analysis were conducted.

Finally, all samples were lyophilized using a Virtis Freezemobile 24 lyophilizer (Virtis, Gardner, NY, USA), ground in a conventional mill for 2 min and then analyzed. Pasting properties and degree of gelatinization were measured as described in 2.6 and 2.7.

2.3. Moisture content analysis

The moisture content of treated rice grains was determined on a wet weight basis using a Sartorious MA 30 moisture analyzer (Sartorious, Goettingen, Germany). Approximately 3 g of rice was dried in the analyzer at 130 °C to constant weight (Ahromit, Ledward & Niranjan, 2007). The moisture content was expressed on a wet weight basis.

2.4. Volume expansion ratio

This parameter was calculated as the ratio of the volume of pre-soaked rice to the volume of raw rice. Ten gram rice was added to a 100 mL cylinder (in triplicate) already filled with 50 mL of water and the increase in volume was recorded as the volume of raw rice. Then all of the samples were soaked for 30, 45, and 60 min in water, and the increase in volume was measured by cylinder method at the end of the soaking time (Butt et al., 2008).

2.5. Texture analyses

An instrumental texture profile analysis was performed on 2 g aliquots using a table-top TA-XT2 texture analyzer (Stable Micro Systems, Ltd. Godalming, Surrey, UK). The sample was arranged in a single-grain layer on the base platform of the analyzer. A 2 inch (50 mm) diameter cylinder plunger was set at 4 mm above the base. A two-cycle compression force vs. distance program was used. The upper compression plunger traveled 3.6 mm at a test speed of 1 mm/s, returned, and repeated the cycle. Three replicate aliquots were tested on each sample and the recorded values from the resulting two curves for each test were used for texture profile analysis (TPA), which includes attributes of hardness, cohesiveness, springiness, gumminess, chewiness and resilience. These TPA curve attributes represent standard calculations as described by Lyon, Champagne, Vinyard, and Windham (2000). A distance (rather than percentage) compression test was performed for the TPA experiments, with the analysis starting when the distance between the plunger and bottom