Food Chemistry xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Food Chemistry

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

Polishing and parboiling effect on the nutritional and technological properties of pigmented rice

Flávia Fernandes Paiva [a,b], Nathan Levien Vanier [a,b,*], Jose De J. Berrios [b], Vânia Zanella Pinto [a], Delilah Wood [b], Tina Williams [b], James Pan [b], Moacir Cardoso Elias [a]

[a] Department of Agroindustrial Science and Technology, Federal University of Pelotas, 96160-000 Capão do Leão, RS, Brazil
[b] Healthy Processed Foods Research Unit, WRRC, ARS, United States Department of Agriculture, 800 Buchanan Street, Albany, CA 94710, United States

ARTICLE INFO

Article history:
Received 15 August 2014
Received in revised form 27 December 2014
Accepted 10 February 2015
Available online xxxx

Keywords:
Red rice
Black rice
Structure
Proximate composition
Free and bound phenolics
Cooking quality

ABSTRACT

This study aims to evaluate the effects of polishing and parboiling on proximate composition, structure, phenolic compounds, antioxidant activity, cooking time and hardness of IAC-600 black rice cultivar and MPB-10 red rice lineage. Proximate analysis and light micrographs revealed higher migration of red rice proteins than black rice proteins to the endosperm as a result of parboiling. Parboiling reduced the ash content of red rice while no difference was determined in black rice. Gelatinized starch granules from both genotypes showed similar appearance. There was a decrease in relative crystallinity on both black and red rice subjected to parboiling, which was an indicative of crystallites disruption. Polishing removed more than 90% of free phenolics for both genotypes, while parboiling allowed the partial preservation of free phenolics content in polished rice. Parboiling induced an increase in the cooking time of red rice, but a decrease in the cooking time of black rice.

1. Introduction

Pigmented rice grains (*Oryza sativa* L.), such as black and red rice, possess phenolic compounds distributed in their bran layers. Phenolics compounds have been shown to promote several health benefits for consumers, including antioxidant, anticarcinogenic, antiallergic, anti-inflammatory, antiatherosclerosis and hypoglycemic activities (Deng et al., 2013). Anthocyanins, mainly cyanidin-3-*O*-glucoside, are the main phenolic constituent of black rice grains (Abdel-Aal, Young, & Rabalski, 2006), while proanthocyanidins – also known as condensed tannins – have been reported as the main phenolic constituent of red rice grains (Cai, Sun, Xing, Luo, & Corke, 2006; Gunaratne et al., 2013).

Rice is mainly consumed worldwide as polished rice. The polishing process is performed by rice industries in order to improve the physical characteristics and sensory properties of rice, as well as to increase its storage stability (Monks et al., 2013). This processing technique removes the bran and the germ of the rice caryopsis. The bran layers are rich in proteins, fibers, vitamins, and fat; while the germ is mainly rich in fat. Thus, although the polishing process provides benefits to the physical, sensorial and preservative properties of rice, the nutritional properties are diminished. Pigmented rice cultivars, differently from non-pigmented rice cultivars, present their bran layers rich in phenolic compounds, and thus, polishing cause a detrimental nutritional effect on pigmented rice (Paiva et al., 2014).

Parboiling of rice has been an effective processing technique to increase storage stability of rice with minimal changes on nutritional quality (Heinemann, Behrens, & Lanfer-Marquez, 2006; Min, McClung, & Chen, 2014; Oli, Ward, Adhikari, & Torley, 2014). Moreover, parboiling can reduce the level of kernel breakage during polishing (Buggenhout, Brijs, & Delcour, 2013). Parboiling consists of three additional steps to rice industrialization: soaking, pressure steaming, and drying prior dehusking. After these steps, rice follows conventional processing steps. The main phenomena that occur in rice during parboiling are: (1) the transfer of bran components to the inner layers of rice caryopsis during the soaking step, (2) inactivation of lipases due to heat treatment, and (3) starch gelatinization (Demont et al., 2012).

The effects of parboiling on physicochemical, structural, and nutritional properties of non-pigmented rice are well-known. However, few studies were conducted regarding the impact of parboiling on the functional properties of pigmented rice cultivars. Recently, Walter et al. (2013) evaluated the antioxidant properties of red and black rice cultivars as a function of polishing, parboiling

* Corresponding author at: Department of Agroindustrial Science and Technology, Federal University of Pelotas, 96160-000 Capão do Leão, RS, Brazil. Tel./fax: +55 53 32757258.
E-mail address: nathanvanier@hotmail.com (N.L. Vanier).

http://dx.doi.org/10.1016/j.foodchem.2015.02.047
0308-8146/

and cooking, while Min et al. (2014) studied the effects of parboiling on antioxidant compounds from brown, purple and red rice genotypes. To our knowledge, there is limited information regarding functional properties of pigmented rice cultivars subjected to parboiling, with no reports available on proximate composition, structure and physicochemical properties of parboiled-treated pigmented rice.

The aim of this study was to evaluate the effects of polishing at 12% degree of milling (DOM) and parboiling on proximate composition, structural properties, phenolic compounds, antioxidant activity, cooking time and hardness of IAC-600 black rice cultivar and MPB-10 red rice lineage.

2. Materials and methods

2.1. Materials

Black rice cultivar IAC-600 and red rice lineage MPB-10 were cultivated under an irrigation system in Pelotas, State of Rio Grande do Sul, Brazil. The rice grains were harvested when the moisture content was approximately 20%, transported to the Postharvest, Industrialization and Quality of Grains' Laboratory at the Federal University of Pelotas and subjected to cleaning and drying processes until a 13% moisture content was achieved. The method described by Bertoft, Piyachomkwan, Chatakanonda, and Sriroth (2008) was used to determine the amylose content of the rice samples. The IAC-600 black rice cultivar presented 23.4% amylose content while the MPB-10 red rice lineage presented 32.0% amylose content.

2.2. Rice processing

To obtain unpolished grains, both black and red rice (100 g) were dehusked using a Zaccaria rice machine (Type PAZ-1-DTA, Zaccaria, Brazil). To obtain polished grains, dehusked black and red rice samples were polished using the same Zaccaria rice machine, until 12% degree of milling (DOM). The DOM was determined using the following equation: DOM = [1 − (weight of the polished rice/weight of the rough rice)] × 100. Parboiled rice was obtained by placing 300 g of the rough rice (grains with the hulls) into 3 liter-beakers. One liter of distilled water was added to the beakers containing the rough rice. The material was maintained in a water bath at 60 °C for 4 h. The hydrated rough rice was autoclaved (Bio Eng. A-30, Bio Eng., Brazil) for 10 min at 108 °C, which constituted the second step of the rice parboiling process. The hydrated, autoclaved rough rice was allowed to stand at room temperature overnight. Finally, the rough rice was placed in an oven dryer (Model 400-2ND, Nova Ética, Brazil) set at 38 °C until they achieved a 13% moisture content. The dried parboiled rough rice (100 g) were dehusked and polished using the same Zaccaria rice machine used for non-parboiled grains. The dehusked parboiled grains constituted the parboiled unpolished treatment, while the dehusked and polished grains constituted the parboiled polished treatment. The parboiled polished rice was milled to 12% DOM. Broken grains of all treatments were removed using a laboratory grader of the same Zaccaria rice machine (Type PAZ-1-DTA, Zaccaria, Brazil). Grains from unpolished, polished, parboiled unpolished and parboiled polished treatments, from black and red rice genotypes, were ground through 70 mesh screen (210 microns) using a laboratory mill (Perten 3100, Perten Instruments, Sweden). Analyses of black and red rice were performed in non-parboiled and parboiled unpolished and polished rice.

2.3. Proximate analysis

The moisture content of the rice samples was determined using a drying oven set at 105 ± 3 °C, with natural air circulation for 24 h, following the recommendations of the American Society of Agricultural Engineers (ASAE, 2000). Moisture content was expressed as percentage (%). Fat content was determined following method 30-20 of the American Association of Cereal Chemists (AACC, 1995). Nitrogen content was determined according to AACC method 46-13 (AACC, 1995), and the protein content was obtained using a conversion factor of nitrogen to protein of 5.95. Ash content was determined according to the AACC method 08-01 (AACC, 1995).

2.4. Light micrographs

To investigate the effects of parboiling on protein and starch constituents of black and red rice grains, 10 rice kernels were fixed, cut into midsections and left in the fixative solution overnight. The fixative solution was composed of 2% Formaldehyde, 2.5% Glutaraldehyde, and 2.5 mM Calcium Chloride in 0.1 M Sodium Cacodylate with a pH at 6.9. After fixation, the kernel midsections were rinsed in 0.1 M Sodium Cacodylate and dehydrated in a graded ethanol/butanol series, followed by infiltration with Technovit 7100 monomer (with hardener) and placed in the fridge to polymerize. Plastic molds were trimmed down and sections of 2 μm and 4 μm were made with a rotary microtome for sample staining. Aleurone layer and endosperm were identified by staining in Periodic Acid-Schiff's counterstained using 1% Alcian Blue B in 3% acetic acid, and viewed in brightfield. The samples were viewed and photographed using a Leica DM4000B compound light microscope (Leica Microsystems, Wetzlar, Germany) and their digital images collected using a digital camera (Leica DFC 500, Leica Microsystems Inc., Buffalo Grove, IL, USA).

2.5. Scanning electron micrographs

The effects of parboiling on starch granules microstructure were evaluated by scanning electron microscopy (SEM). Rice grains were cut into midsections and placed directly into vials containing 2% Formaldehyde, 2.5% Glutaraldehyde, and 2.5 mM Calcium Chloride in 0.1 M Sodium Cacodylate buffer, pH 6.9, and stored at 4 °C for further processing. Samples were rinsed three times in 0.1 M Sodium Cacodylate buffer, just before processing. Samples for SEM were dehydrated in a graded series of ethanol (30%, 50%, 70%, 95% and 3 × 100%, 30 min per exchange) and cryofractured in liquid nitrogen. Cryofracturing consisted of dropping the dehydrated midsections into liquid nitrogen and fracturing with a pre-chilled razor blade held in a vice grip. The fractured rice pieces were collected with a chilled tweezers, returned to 100% ethanol and dried in a Tousimis Autosamdri-815 (Rockville, MD, USA) Critical Point Dryer. Critical point drying is an established method of dehydrating biological tissue prior to examination in the Scanning Electron Microscope. The fractured rice pieces were then mounted onto aluminum specimen stubs using double adhesive coated carbon tabs (Ted Pella, Inc, Redding, CA, USA), and the mounted samples were coated with gold–palladium in a Denton Desk II (Denton Vacuum, Inc., Moorestown, NJ, USA) sputter coating unit. The samples were viewed and photographed in a Hitachi S4700 field emission scanning electron microscope (Hitachi, Japan).

2.6. Free and bound phenolics content

2.6.1. Extraction of phenolics

The extraction of free and bound phenolics was performed according to the method described by Qiu, Liu, and Beta (2010).

Please cite this article in press as: Paiva, F. F., et al. Polishing and parboiling effect on the nutritional and technological properties of pigmented rice. *Food Chemistry* (2015), http://dx.doi.org/10.1016/j.foodchem.2015.02.047