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Original Research Article

Thiamine content and technological quality properties of parboiled rice treated with sodium bisulfite: Benefits and food safety risk

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ABSTRACT

Rice is a staple food for more than half of the world's population. The parboiling process is known to increase the nutritional value of milled rice, but the process darkens the grains, with a corresponding negative effect on consumer acceptability. The aim of this study was to evaluate the effects of using different concentrations of sodium bisulfite (0, 0.2, 0.4, 0.6, 0.8, 1.0%) during the soaking step of rice parboiling process on the thiamine content and technological properties of parboiled rice. Moreover, the residual sulfite content in parboiled grains was also evaluated. The lowest concentration of 0.2% sodium bisulfite was able to significantly ($p < 0.05$) promote a whiter colour, a decrease in the percentage of stained grains, and an increase in the percentage of completely gelatinized grains in the parboiled rice, compared to rice without sodium bisulfite treatment. However, the use of sodium bisulfite significantly ($p < 0.05$) reduced the thiamine content, which is considered a risk associated with the treatment.

1. Introduction

Consumed all over the world, rice is an important source of energy for the population worldwide. Rice is generally the cheapest and richest source of carbohydrates, proteins, vitamins and minerals for very poor populations, which makes it a powerful, health-promoting ally in minimizing hunger. The majority of consumers prefer well-milled white rice with little or no bran remaining on the endosperm (Heinemann et al., 2006; Monks et al., 2013). The milling process increases the preservation of rice during storage by removing the fat-rich embryo and the bran layers of rice caryopsis. On the other hand, the milling process promotes a significant decrease in vitamins and mineral content in rice due to bran removal (Lamberts et al., 2007; Monks et al., 2013). The parboiling process can be carried out in order to obtain milled rice with a better nutritional composition than milled white rice (Padua and Juliano, 1974).

The parboiling process consists of three additional steps in conventional rice processing, which are: soaking, pressure steaming, and drying prior to dehusking. After these steps, rice follows the same process as for conventional rice. 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, naturally distributed in the bran, due to heat treatment, and (3) starch gelatinization (Demont et al., 2012). Although parboiling provides benefits to the nutritional and technological properties of rice, such as higher vitamin content, longer shelf-life stability and decrease in the percentage of broken grains after dehusking and milling compared to non-parboiled milled rice, the parboiled rice is dark, which negatively affects rice consumer acceptability (Bhattacharya, 1996).

It has been hypothesized that the colour changes that occurs in rice during parboiling are caused by (1) diffusion of husk and bran pigments; (2) non-enzymatic browning of the Maillard type; and (3) enzymatic colour changes during the soaking step (Ali and Bhattacharya, 1980; Bhattacharya and Rao, 1966;

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Lamberts et al., 2006). More recently, Lamberts et al. (2008) studied the formation of brown pigments in rice as an effect of the parboiling conditions, and suggested that Maillard reactions were mainly responsible for the browning of rice during the steaming step of parboiling. Maillard reactions involve the reaction of carbonyl groups of reducing sugars and the amino groups of amino acids (mainly lysine), peptides, or proteins.

Several food additives have been used to prevent the browning of foods. These food additives can be synthetic chemicals or natural substances added to food for colour preservation or for improving its flavour, taste or appearance (FAO/WHO, 2008). Among the main food additives, sulfites (sodium and potassium sulfite, bisulfites and metabisulfites, sulphur dioxide, sodium sulphate) are widely used by the food industry as antioxidants, decolourants, flour treatment agents, and preservatives (Zhang et al., 2014). Additionally, sulfite technology has been used to control postharvest losses in banana (Williams et al., 2003), green figs (Cantín et al., 2011), lemon (Smilanik et al., 1995), litchi (Lichter et al., 2000) and raspberry (Spayd et al., 1984). Although there are no studies regarding the use of sulfites in rice processing, it is possible that the technological properties of rice could be improved by adding sulfites during the soaking step of rice parboiling. However, this technique may represent a food safety risk, if thiamine content is reduced or destroyed.

The aim of this study was to evaluate the effects of using different concentrations of sodium bisulfite (0, 0.2, 0.4, 0.6, 0.8, 1.0%) during the soaking step of rice parboiling on thiamine and sulfite content, as well as to examine important technological properties of parboiled rice such as broken grains and stained grains percentage, whiteness, cooking time, hardness, and percentage of completely gelatinized and non-gelatinized grains. In addition, the pasting properties of parboiled rice were determined.

2. Materials and methods

2.1. Materials

Long grain rice (*Oryza sativa* L.) from IRGA 417 cultivar (high-amylose), cultivated under irrigation system on a farm in Pelotas, State of Rio Grande do Sul, Brazil, was harvested when the moisture content was approximately 20%. The rice was placed in raffia bags and immediately transported to Laboratório de Pós-Colheita, Industrialização e Qualidade de Grãos of the Universidade Federal de Pelotas, where the study was carried out. The foreign matter and impurities were manually removed from the grains prior to the drying process. The grains were subjected to artificial drying with air temperature of 35 °C until the grain achieved 13% moisture content.

2.2. Sample preparation

Dried and cleaned rice samples (300 g) were placed into 3-L beakers. In order to evaluate the impact of using sodium bisulfite during the soaking step of parboiling on technological properties and thiamine content of rice, sodium bisulfite (Sigma–Aldrich Co., St. Louis, MO, USA) solutions at 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0% were prepared with distilled water. One litre of each solution was added to the different beakers containing the rice samples. The material was maintained in a water bath at 65 °C for 6 h. Then, the hydrated rice grains were autoclaved (Bio Eng. A-30, Bio Eng., São Paulo, SP, Brazil) for 10 min at 116 °C, which constituted the second step of the rice parboiling process. The hydrated-autoclaved rice grains were allowed to stand at room temperature overnight. The final parboiling step was conducted in an oven (Model 400-2ND, Nova Ética, São Paulo, SP, Brazil) set at 38 °C, where the grains were dried until they achieved 13% moisture content.

The dried rice grains (100 g) were dehusked and polished using a Zaccaria rice machine (Type PAZ-1-DTA, Zaccaria, Limeira, SP, Brazil). Brown rice samples, after cleaning and grading, were polished for 50 s. The degree of milling (DOM) was determined using the following equation: DOM = [1 − (weight of the milled rice/weight of the rough rice)] × 100. All the samples presented similar DOM. Broken grains were removed using a laboratory grader of the same Zaccaria rice machine. The non-parboiled rice grains and the grains subjected to parboiling under different sodium bisulfite concentrations were ground through a 70-mesh screen (210 μm) using a laboratory mill (Perten 3100, Perten Instruments, Hägersten, Sweden).

2.3. Thiamine and residual sulfite content

Thiamine content was determined following fluorometric method 957.17 of the American Organization of Analytical Chemists International (AOAC, 2005), in triplicate. Sulfite content was determined according to AOAC method 990.28 (AOAC, 2005), in triplicate.

2.4. Broken grains

The length of each broken grain, obtained by using the laboratory grader of the Zaccaria rice machine, was measured with a digital calliper (Mitutoyo, Santo Amaro, SP, Brazil). Grains with a length of less than 4.5 mm were considered broken, which is the directive provided in the Brazilian Official Standards for Rice Classification (BRASIL, 2009). The percentage (%) of broken grains was determined using the following equation: Broken grains (%) = (weight of grains less than 4.5 mm − length/weight of the milled rice) × 100.

2.5. Stained grains

The percentage of stained rice was determined in 100 g of grain, in triplicate, according to the method described by the Brazilian Official Standards for Rice Classification (BRASIL, 2009). The grains or broken grains that presented dark stains and/or fungal contamination (mould or mildew) visible to the naked eye, regardless of the size of the affected area, were considered as infected. The percentage (%) of stained rice was determined using the following equation: Stained grains (%) = (weight of stained rice/weight of the milled rice) × 100.

2.6. Whiteness

The rice whiteness was recorded with a Zaccaria milling metre (MBZ-1, Zaccaria, Limeira, SP, Brazil), which is widely used by the rice industries worldwide. The results were expressed using the scale provided by the meter in GBZ units.

2.7. Completely gelatinized and non-gelatinized grains

Completely gelatinized and non-gelatinized grains were visually evaluated by using polarizing filters, following the Brazilian Official Standards for Rice Classification (BRASIL, 2009). Briefly, 5 replicates of 50 grains were distributed in a polarizing filter above an artificial light (Polarizadora de arroz 11635, Comag, Panambi, RS, Brazil). The grains were placed side by side. Another polarizing filter was placed above the grains in a position that provided the misalignment of the light beam by the filters. Completely gelatinized grains are totally vitreous under polarized light, since there is no light diffraction within the grain, while