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Antioxidant properties of rice grains with light brown, red and black pericarp colors and the effect of processing

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ABSTRACT

The present work evaluated the concentration of total soluble phenolic compounds (TSPCs) and antioxidant activity (AOA) of rice grains with light brown, red and black pericarp colors and the processing effect on the concentration of TSPCs in the grain. Brown rice grains of ten ecotypes and six cultivars with red pericarp, one with a black pericarp and one with a light brown pericarp color, were evaluated. The concentration of TSPCs and AOA of rice grains with different processing (brown, polished, parboiled brown and parboiled polished) was determined, and the concentration of TSPCs was also determined in raw and cooked grains. Significant differences were observed in the concentrations of TSPCs and AOAs among genotypes with higher values obtained for grains with red and black pericarp colors, and a positive and significant correlation between these parameters was found. Parboiling reduced the TSPCs concentration in the grains due to the loss of part of them in the processing water, thermal decomposition and, possibly, interaction with other components. This reduction is related to the lower AOA in these grains. In a similar way, cooking also reduced the concentration of TSPCs, especially in brown and polished grains.

1. Introduction

Phenolic compounds (polyphenols) are found in a variety of foods, including fruits, vegetables and grains, and the concentrations and types of compounds vary among different foods due to genetic factors, environmental factors and processing conditions (Kris-Etherton et al., 2002). Therefore, the quantity of polyphenols in the diet is diverse, depending on the type and quantity of food consumed.

Rice, one the main foods in the diet of most populations, may have an important role in the concentration of antioxidants ingested daily. Several compounds have already been identified in this cereal, mainly phenolic acids and anthocyanins (Chen et al., 2006; Goffman & Bergman, 2004; Hu, Zawistowski, Ling, & Kitts, 2003; Hudson, Dinh, Kokubun, Simmonds, & Gescher, 2000; Oki et al., 2002; Tian, Nakamura, & Kayahara, 2004; Yawadio, Tanimori, & Morita, 2007; Zhou, Robards, Helliwell, & Blanchard, 2004). Researchers have demonstrated a positive correlation between the concentration of phenolic compounds and the antioxidant activity (AOA) (Goffman & Bergman, 2004; Zhang et al., 2006), which was also observed for other foods rich in these compounds.

Similar to other cereal grains, the phenolic compounds in rice exist in the soluble and insoluble (bound) form, with the soluble form representing 38% (Adom & Liu, 2002) to 60% (Mira, de Massaretto, Pascual, & Lanfer-Marquez, 2009) of the total polyphenols content in light brown rice grains, and around 81% in red and black pericarp color grains (Mira et al., 2009). The type and concentration of polyphenols in the rice grain vary among genotypes and are related mainly to the pericarp color. Normally, grains with red and black pericarp colors have a higher concentration of phenolic compounds compared to those with a light brown pericarp color (Tian et al., 2004; Zhou et al., 2004). Furthermore, the concentration of these compounds is also affected by processing. In rice, polyphenols are mainly associated with the pericarp, which is removed during processing to obtain polished grains. This is the main way rice is prepared for consumption in Brazil, reducing the concentration of these compounds in the grain (Hu et al., 2003; Zhou et al., 2004). Rice can also be hydrothermally treated in a process known as parboiling, resulting in parboiled rice, and rice is cooked before its consumption. Little is known about the effect of these two procedures on the polyphenols in the grain.

Thus, the present work evaluated the concentration of total soluble phenolic compounds (TSPCs) and AOA of rice grains with light brown, red and black pericarp colors and the effect of processing on the concentration of phenolic compounds in the grain.

Abbreviations: ABTS, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonate); AOA, antioxidant activity; DPPH, 2,2-diphenyl-1-picrylhydrazyl; TE, Trolox equivalent; Trolox, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid; TSPCs, total soluble phenolic compounds.

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2. Materials and methods

2.1. Experimental material

Rice grains were cultivated in a field experiment in the 2006–2007 growing season with equal growing conditions in the experimental area of the Agriculture Department of Universidade Federal de Santa Maria, Santa Maria, RS, Brazil.

The cultivated rice included the following: ten rice ecotypes (genetically distinct geographic rice varieties) with a red pericarp color from different regions of Rio Grande do Sul state collected by researchers from the Instituto Rio Grandense do Arroz (IRGA), called Ec1A, Ec1B, Ec2A, Ec2B, Ec2C, Ec2D, Ec3A, Ec3B, Ec3C and Ec4A; five rice cultivars with a red pericarp color from the northeast region of Brazil collected by researchers from Embrapa Meio-Norte, called PB1, PB4, PB5, PB11 and PB13; one rice cultivar with a red pericarp color from Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri), called Epagri; one rice cultivar with a black pericarp color from Instituto Agronômico Campinas (IAC), called IAC 600; and one rice cultivar with a light brown pericarp color from IRGA, called Irga 417.

After harvest, the grains were dried to 13% ± 1% of moisture at a grain mass temperature below 40 °C. For each ecotype and cultivar, the starting material was around 10,000 g. These samples were divided in 1000 g samples for the various processing conditions, resulting in samples of around 800 g after each processing. These samples were further subdivided in samples of 200 g used for the laboratory analyses.

2.2. Grain processing

For the laboratory analyses, the grains were processed in different ways as follows: brown, polished, parboiled brown and parboiled polished. The grains were evaluated both raw and cooked. To obtain the brown grains, grains were dehulled, and the absence of lines in the grains was observed, indicating that no bran was lost during processing. To obtain the polished grains, the dehulled grains were polished to remove the external layers of the grain (bran). Rice was parboiled according to the adapted methodology of Elias, Rombaldi, Silva, Nora, and Dias (1996). The grains with the hull were soaked (grain mass:water volume ratio 1:1.5) in heated water at 65 °C ± 2 °C for 300 min and autoclaved at 116 °C ± 1 °C (pressure 0.6 kPa ± 0.05 kPa) for 10 min. After this treatment, the samples were dried to 13% ± 1% moisture at a grain mass temperature below 40 °C. To obtain the parboiled brown rice, the grains were dehulled, and to obtain the parboiled polished rice, grains were dehulled and polished. To evaluate the cooked rice, the grains were cooked in a grain mass: water volume ratio of 1:2.5 for 30 min and then dried at 50 °C. The grains were ground to obtain the right particle size for the analyses.

2.3. Laboratory analyses

To evaluate the concentration of TSPCs and AOA, the samples were extracted according to the modified methodology of Iqbal, Bhanger, and Anwar (2005) and Pérez-Jiménez and Saura-Calixto (2005). A one-gram sample was homogenized with 20 mL of 80% methanol in a 50 mL Falcon tube and agitated for 1 h at room temperature. After this period, the sample was centrifuged for 10 min at 3000 rpm, and the supernatant was separated. To the remaining residue, 20 mL of 80% methanol (pH 2.0) was added, and the same procedure of agitation, centrifugation and separation of the supernatant was completed. To this residue, 20 mL of 70% acetone was added, and the same procedure of agitation, centrifugation and separation of the supernatant was completed. The three supernatants were mixed and used for the analysis of TSPCs and AOA. The extractions were performed in triplicate.

The TSPCs were quantified by the Folin–Ciocalteu methodology (Iqbal et al., 2005; Singleton, Orthofer, & Lamuela-Raventós, 1999). An 80-μL aliquot of the extract (sample) was diluted in 2 mL of distilled water, and 200 μL of 0.25 N Folin–Ciocalteu reagent was added. After 3 min, 1 mL of 7.5% sodium carbonate was added. The reaction mixture was incubated for 2 h at room temperature in the dark to complete the reaction. The absorbance was measured in a spectrophotometer at 765 nm. At the same time, a blank containing methanol instead of the sample was analyzed. A gallic acid standard curve was used, and the results were calculated as the gallic acid equivalent (mg GAE) per 100 g grain (dry basis). The reactions were performed in triplicate, and the mean value was obtained.

The AOA was quantified by the measurement of 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity (Brand-Williams, Cuvelier, & Berset, 1995). Before running the reaction, the spectrophotometer was blanked with methanol, and the DPPH solution was diluted with methanol to reach an absorbance of 1.1 ± 0.02 at 515 nm. To 100 μL of the extract (sample), 1.9 mL of the DPPH solution was added. A blank was simultaneously prepared with 100 μL of methanol. The reaction mixture was incubated for 24 h at room temperature in the dark to complete the reaction. The absorbance was measured in a spectrophotometer at 515 nm. When the absorbance was below 0.2, the samples were diluted and reanalyzed. The AOA was calculated as a 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) equivalent (mmol TE) per g of grain by comparison to a standard curve. The reactions were performed in triplicate, and the mean value was obtained.

2.4. Experimental design and statistical analysis

The experiment was conducted in a completely random design. The obtained results were evaluated by analysis of variance, and the means were compared by Tukey's Test at a 5% error probability.

3. Results and discussion

The concentration of TSPCs differed significantly among the genotypes (Table 1). Higher concentrations of TSPCs were observed for the grains with red and black pericarp colors, which were 7 to 15 times higher than the TSPCs concentrations of grains with a light brown pericarp color. Similar results were obtained by other researchers.

Table 1
Concentration of TSPCs and AOA of brown rice grains with light brown, red and black pericarp colors.

	TSPCs (mg GAE 100 g^{-1})[1]	AOA (mmol TE g^{-1})[2]
Irga 417[3]	65.14 ± 0.95^{j}	4.70 ± 0.38^{f}
Epagri[4]	794.88 ± 4.67^{de}	62.57 ± 2.61^{abc}
PB 1[4]	761.30 ± 7.42^{f}	64.13 ± 4.13^{abc}
PB 4[4]	825.00 ± 6.14^{cd}	65.65 ± 2.93^{abc}
PB 5[4]	684.63 ± 13.15^{g}	60.24 ± 0.70^{bc}
PB 11[4]	771.23 ± 8.82^{ef}	66.58 ± 1.35^{ab}
PB 13[4]	837.65 ± 10.05^{c}	61.55 ± 2.96^{bc}
Ec1A[4]	972.99 ± 4.67^{a}	68.83 ± 3.96^{a}
Ec1B[4]	478.72 ± 13.29^{i}	37.19 ± 1.44^{e}
Ec2A[4]	531.49 ± 5.88^{h}	44.42 ± 2.03^{d}
Ec2B[4]	529.48 ± 10.43^{h}	44.31 ± 2.59^{de}
Ec2C[4]	664.55 ± 6.10^{g}	50.36 ± 3.08^{d}
Ec2D[4]	677.54 ± 8.52^{g}	49.89 ± 1.36^{d}
Ec3A[4]	926.70 ± 3.21^{b}	66.37 ± 2.75^{ab}
Ec3B[4]	787.09 ± 10.54^{ef}	58.65 ± 1.10^{c}
Ec3C[4]	818.71 ± 4.13^{cd}	63.71 ± 0.86^{abc}
Ec4A[4]	664.68 ± 13.34^{g}	49.70 ± 0.19^{d}
IAC 600[5]	943.98 ± 25.46^{ab}	60.04 ± 2.07^{bc}

[1]TSPCs expressed as mg GAE per 100 g grain, dry basis; [2]AOA expressed as mmol TE per g grain, dry basis; [3]light brown pericarp color; [4]red pericarp color; [5]black pericarp color; results expressed as means ± standard deviations; and means followed by the same letter in the column do not differ significantly by Tukey's test at 5% of error probability.