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Technological, physicochemical and sensory changes of upland rice in soaking step of the parboiling process

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ABSTRACT. The aim of this study was to evaluate the effect of combinations of soaking temperature and time during the parboiling on the technological, physicochemical and sensory quality of two upland rice cultivars. The milling degree for BRS Primavera and BRS Sertaneja cultivars ranged from 7.11 to 8.89 g 100 g^{-1} and 7.62 to 8.91 g 100 $g^{-1}$and the head yield from 63.77 to 69.26 g 100 g^{-1} and from 73.22 to 75.40 g 100 g^{-1}, respectively. The ash content for parboiled BRS Sertaneja increased up to 68%; regarding protein, the content increased up to 10% and for lipids, the values increased up to 86%, approximately, after processing. The higher the soaking temperature, the lower the milling degree and head yield. The parboiled rice BRS Primavera achieved higher contents of ash and lipid in relation to non-parboiled milled rice, while the BRS Sertaneja obtained higher ash, protein, lipid, and crude fiber contents. Parboiled rice samples had higher yield and cooking time than milled rice samples. The condition of soaking at 65°C for 60 min. and 60ºC for 112 min. was sufficient for the acceptance of all sensory attributes evaluated in BRS Primavera, and 65ºC for 420 min. in BRS Sertaneja.

Keywords: *Oryza sativa* L., milling degree, head yield, proximate composition, cooking quality, acceptability.

Mudanças tecnológicas, físico-químicas e sensoriais de arroz de terras altas na etapa de encharcamento da parboilização

RESUMO. O objetivo deste estudo foi avaliar o efeito das combinações de temperatura e tempo de encharcamento durante a parboilização na qualidade tecnológica, físico-química e sensorial de duas cultivares de arroz de terras altas. O grau de polimento para as cultivares BRS Primavera e BRS Sertaneja variou de 7,11 a 8,89 g 100 g^{-1} e 7,62 para 8,91 g 100 g^{-1} e o rendimento de inteiros de 63,77 a 69,26 g 100 g^{-1} e de 73,22 a 75,40 g 100 g^{-1}, respectivamente. Após o processamento, o conteúdo de cinzas para a BRS Sertaneja aumentou até 68%; de proteínas em até 10% e para lipídios até 86%. Quanto maior a temperatura de encharcamento, menor o grau de polimento e produção de grãos inteiros. O arroz parboilizado da BRS Primavera obteve maior teor de cinzas e de lipídios em relação ao arroz beneficiado não parboilizado, enquanto a BRS Sertaneja obteve maiores teores de cinzas, proteína, lipídios e fibra bruta. Amostras de arroz parboilizado obtiveram maiores rendimentos e tempos de cozimento do que as amostras de arroz branco, sendo que a condição de água a 65°C por 60 min. e 60ºC por 112 min. foi suficiente para a aceitação de todos os atributos sensoriais avaliados na BRS Primavera, e 65ºC por 420 min. na BRS Sertaneja.

Palavra-chaves: *Oryza sativa* L., grau de polimento, rendimento de inteiros, composição centesimal, qualidade de cozimento, aceitabilidade.

Introduction

Wheat, corn, and rice are the most important cereals worldwide, which compose the basis of human nutrition and contribute with about half the energy and protein intake of all individuals. Brazil stands out as the largest rice producer in Latin America and the ninth world's largest producer (FAO, 2013), with a production of 730,000,000 tons of paddy in the 2012 harvest (CONAB, 2012). The Brazilian Agricultural Research Corporation (Embrapa) has released several high-quality cultivars, which are resistant to pests and diseases and adapted to the new agricultural system of the Brazilian *Cerrado*, which provide less risk for farmers, high quality of grains and good commercial acceptance (FERREIRA et al., 2005). The use of parboiling rice has increased significantly in recent decades. The parboiling process is a process that involves grain soaking, steaming, or boiling, followed by cooling and slow drying. During this treatment, starch gelatinization occurs, which passes from the crystalline to amorphous form, making the texture of the endosperm more compact and translucent. Thus, rice parboiling can lead to significant changes in proximate composition and cooking quality (AMATO; ELIAS, 2005). Rice is a major foodstuff in Brazilian food habits, being consumed in its different forms on a daily basis (BEHRENS et al., 2007). Given the trend of increasing consumption of parboiled rice and lack of specific studies on the effects of this type of processing on nutritional and technological characteristics of upland rice cultivars, it is important to provide information on the processing benefits and optimization of process conditions. In this context, this study investigated the influence of the soaking variables (temperature and time of immersion in water) on the technological (milling degree and head yield), proximate composition, apparent amylose content and cooking time and yield, as well as consumer acceptance of parboiled rice of two upland cultivars (BRS Primavera and BRS Sertaneja).

Material and methods

Rice grains (BRS Primavera and BRS Sertaneja cultivars) from the 2006-2007 harvest, produced under the upland farming system, were hand harvested between April and May 2007 at the Capivara farm, located in the municipality of Santo Antônio de Goiás, Goiás State. Paddy samples with 11 g 100 g^{-1} moisture were packed in cotton cloth bags and stored in cold chamber under relative humidity around 60% and temperature of 27°C. The response surface methodology and the central composite rotational design were used in the parboiling trial, which includes a 2^2 full factorial, three replicates at the center point and four axial points, totaling eleven tests for each cultivar, which were randomly conducted (BARROS NETO et al., 2007).

To perform the soaking step, a 2 L glass beaker and the grain mass / water ratio of 1: 1.6 were used. Four beakers, two for each cultivar, were placed in the bath with water heated at each of the five temperatures used in the design (58, 60, 65, 70, and 72°C). Each beaker was covered with aluminum foil to prevent heat loss and contamination with dirt. Since grains of different cultivars have different dimensions, five distinct times were required for each cultivar to reach the range of 28-32 g 100 g^{-1} of moisture. For the BRS Primavera cultivar, samples were taken from the immersion bath in times of 60, 112, 240, 368, and 420 min. and for the BRS Sertaneja, at times of 180, 250, 420, 590, and 660 min. The samples to different soaking times and temperatures also were subjected to vaporization, being autoclaved for 10 min. at 120°C and 1.1 kgf cm^{-2} of pressure in vertical autoclave (Prismatec, CS-50). Before the drying step, the samples were distributed into polypropylene trays and acclimated for 30 min. Drying was performed in a tray oven (*Nova Ética*, NE-1527), with forced air at 40°C for 2-3 hours until the samples reached 17-18 g 100 g^{-1} of moisture content. During drying, every 20 min., samples were manually turned for a uniform grain moisture. When the samples reached the expected moisture range, the process was interrupted for a period of 24-48 hours for natural heat dissipation and to reach, at the average relative humidity of 43.4%, equilibrium at 13% moisture content. The milling of parboiled grains was performed 24 hours after drying, so that the temperature of each sample would stabilize, coming into equilibrium with the environment, and the grains would become hardened. Grains were hulled (Satake, IHU) and milled (Grainman 60-230-60-2AT), and machines were previously adjusted to avoid breaking of grains and excessive removal of bran. Milled samples were packaged in low-density polyethylene (LDPE) packages and these in opaque polypropylene (PP) pots, being stored under refrigeration (5 ± 1°C) until analysis. After milling, for each parboiled and white rice sample, the milling degree (MD), milling yield (MY) and head yield (HY) were determined in triplicate. The MD was calculated as described by Mohapatra and Bal (2006), by subtracting from one the ratio between the mass of milled grains and the mass of whole grains, and multiplying by 100. The percentage of head and broken grains was calculated after milling in relation to the initial mass of paddy, as established by the Normative Instruction # 6 of Ministry of Agriculture (BRASIL, 2009). The mass of broken and head grains after milling was separated into a sorter 1. This equipment is a cylinder with alveolar walls that separates broken grains, weed seeds and other materials smaller than the grains. The rotational movement of the cylinder allows that the material retained within the alveoli (broken grains) is transferred to an internal gutter, being separated from head grains. The HY was calculated in relation to the initial mass of paddy (COOPER; SIEBENMORGEN, 2007). In addition to the white rice, for the evaluation of the physicochemical characteristics, cooking test, and consumer acceptance, parboiled rice samples were selected, obtained at different soaking times and water immersion temperatures, for each genetic material studied. The criteria adopted for the selection of experiments were lower MD values and higher HY values. Official methods recommended by the AOAC (2005) were used to determine moisture (# 925.10), ash (# 923.03), crude protein (# 960.52), with total nitrogen converted into crude protein, using the factor 5.95; lipid content (920.39) and crude fiber (# 962.09). All tests were performed in duplicate, on a dry basis. The apparent starch amylose content was determined in triplicate by the colorimetric method, according to methodology developed by Martinéz and Cuevas (1989). The pan test or cooking test of white and parboiled rice samples selected from each cultivar were performed in duplicate, according to the methodology developed by Martínez and Cuevas (1989). This analysis simulated the way long-fine type rice is prepared by Brazilian consumers to evaluate cooking time and yield. For the sensory analysis (protocol # 064/2009 from the Federal University of Goiás Ethics Committee) of three parboiled rice samples selected, the acceptance test was used, which was held in two sections, one for each cultivar. One hundred untrained tasters rated the samples using a 9-point hedonic scale for attributes of appearance, aroma, flavor, and texture, according to methodology described by Stone and Sidel (2004) and responded to the survey questionnaire. For sample preparation, the methodology described by Bassinello et al. (2004) was used. Samples were served in a monadic way to allow no comparisons with the random order of balanced presentation. The milling data were assessed using multiple regression adjusted models, analysis of variance and response surface curves were constructed to visualize the effect of independent variables on the dependent ones. For the physicochemical and cooking test data, an entirely randomized design was used, with three original replicates, analysis of variance and comparisons of means by Tukey's test at 5% probability, and for the acceptability data, a randomized block design was used. The data obtained were evaluated by the Statistica for Windows software version 7.1.

Results and discussion

Milling yield

The MD and HY responses for both cultivars showed significant models ($p < 0.05$), with no significant lack of fit ($p > 0.05$), coefficients of determination between 0.85 and 0.96 and coefficients of variation lower than or equal to 7.86%. Thus, models can be used for predictive purposes. In all models, temperature (x_1) was the most expressive variable (Table 1).

For BRS Primavera and BRS Sertaneja cultivars, MD ranged from 7.11 to 8.89 g 100 g^{-1} and from 7.62 to 8.91 g 100 g^{-1}, respectively. In both cultivars, the lowest milling degree occurred at high temperatures (mainly at the range of gelatinization temperature) (Figure 1a and b).

BRS Primavera cultivar also showed lower milling degree at temperatures between 58 and 60°C, probably because it has thinner grains and thus achieved the ideal amount of water faster than the BRS Sertaneja cultivar, being better prepared for the gelatinization of grains in the steaming step, consequently becoming more resistant to subsequent milling process. The MD of both cultivars ranged from 12.49 to 12.56 g 100 g^{-1} in milled rice samples and from 6.41 to 9.33 g 100 g^{-1} in parboiled rice samples. After parboiling, the MD decreased from 52.3 to 74.6% for BRS Primavera samples and from 51.03 to 74.28% for BRS Sertaneja samples, proving that the parboiled rice shows grains more resistant to the removal of the bran layer during the milling process.

BRS Sertaneja cultivar obtained higher milling degree. According to Mohapatra and Bal (2006), thicker grains tend to have higher removal of peripheral layers during the milling process. The HY of BRS Primavera parboiled grains (Figure 1c) was higher at the temperature range from 58 to 60°C and immersion time from 60 to 240 min.; however, at temperatures from 71 to 72°C and immersion times between 60 and 150 min., good head yields were also achieved.

Table 1. Fitted regression models, significance (P); coefficient of determination (R^2); Lack of Fit (LF) and Coefficient of Variation (CV) for the milling degree (MD) and head yield (HY) for upland rice BRS Primavera and BRS Sertaneja cultivars as a function of the immersion temperature and time during the soaking step of the parboiling process.

Response	Fitted model*	P	R^2	FA	CV
	BRS Primavera cultivar				
MD	$y_i = 8.8895 - 1.2708x_1^2 - 0.5025x_1x_2$	0.04	0.85	0.05	7.86
HY	$y_i = 66.3506 + 1.4647x_1^2 - 1.2983x_2$	0.00	0.96	0.74	0.75
	BRS Sertaneja cultivar				
MD	$y_i = 7.6191 - 0.9851x_1 + 0.3075x_1x_2$	0.01	0.90	0.64	5.63
HY	$y_i = 75.4000 + 1.0539x_1 - 0.5874x_1^2 - 0.5424x_2^2$	0.02	0.88	0.07	0.77

y_i : Response (%); x_1 : Temperature (°C): Time (min.) *$p \leq 0.05$ (probability level by F test); expressions in italics in the model mean that the effect, although not significant at 5%, has increased the fitted coefficient of determination.

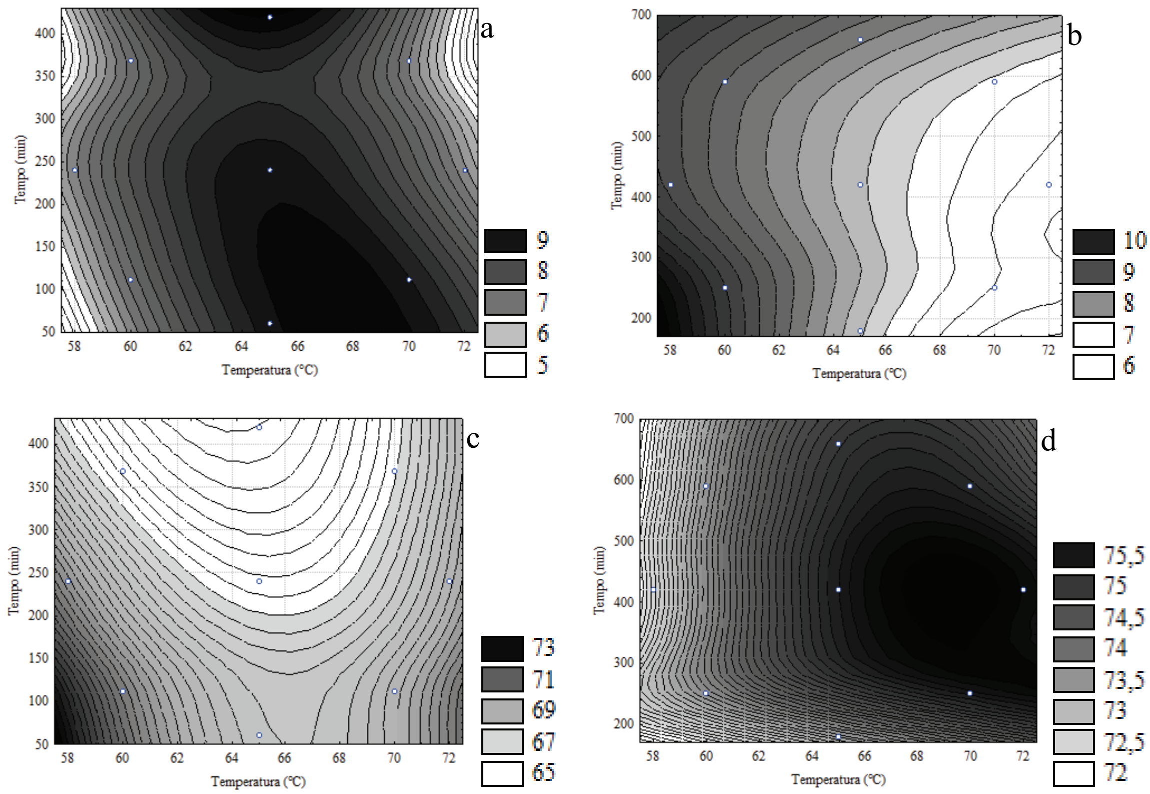

Figure 1. Effect of temperature and immersion time of the soaking step on the milling degree (g 100 g^{-1}) and head yield (g 100 g^{-1}) of BRS Primavera cultivar (a, c) and the BRS Sertaneja cultivar (b, d).

The high HY in the areas of lower temperatures (58 to 60°C) was because it coincided with the ideal area for water absorption, i.e., the grains have absorbed water amounts around 300 g kg^{-1}, resulting in a optimum gelatinization of starch granules and subsequent fusion of broken rice grains, which were prone to break during the milling process. At temperatures above 70°C, a larger amount of starch granules were gelatinized. In addition, retrogradation during cooling could cause the grain to acquire greater resistance to breakage. As a result, BRS Sertaneja cultivar showed higher HY at the temperatures from 65 to 72°C and immersion times between 180 and 660 min. Lower MD was found above 65°C (Figure b), indicating that at this temperature range, a greater number of granules could have been gelatinized. Figure 1d shows that the cultivars have behaved differently regarding the head yield. The characteristics of the grains of each cultivar and the processing conditions influenced the rice milling yield (BHATTACHARYA, 1980). BRS Primavera cultivar showed thinner and longer endosperm, which contributed to the lower HY. After parboiling, the HY of BRS Primavera cultivar ranged from 63.77 to 69.26 g 100 g^{-1}, i.e., it increased from 13.4 to 19.0 g 100 g^{-1} in absolute values. For BRS Sertaneja cultivar, this HY ranged from 73.22 to 75.40 g 100 g^{-1}, i.e., it increased from 12.3 to 13.9 g 100 g^{-1}. With the parboiling process, the BRS Primavera cultivar had a relative increase in the HY higher than that of BRS Sertaneja cultivar because BRS Primavera cultivar has thinner grains, and more prone to breakage, than the BRS Sertaneja cultivar. For both cultivars, the ideal experimental area was below the range of gelatinization temperature (58 to 68°C), with the shortest immersion times, taking into consideration the operational cost and time spent in the soaking step. Based on the responses studied, three treatments of each cultivar were selected to be evaluated as for the physicochemical, sensory, and cooking characteristics. The treatments selected for BRS Primavera cultivar were 58°C for 240 min., 60°C for 112 min. and 65°C for 60 min., while for BRS Sertaneja cultivar, 60°C for 250 min., 65°C for 180 min. and 65°C for 420 min.

Physicochemical characteristics

When comparing the proximate composition between parboiled rice and white rice, it was found that ash, fat, and fiber were the main constituents that showed increments after parboiling in both cultivars (Table 2).

Table 2. Proximate composition (g 100 g^{-1}) and apparent amylose content (g 100 g^{-1}) of grains before cooking, and yield (g 100 g^{-1}) and cooking time (min.) of grains after cooking of milled and parboiled rice samples with different temperature and time binomials for BRS Primavera and BRS Sertaneja cultivars.

	BRS Primavera cultivar			
Characteristic*	Milled rice	58°C for 240 min.	60°C for 112 min.	65°C for 60 min.
Moisture	11.28 ± 0.07^{a}	9.79 ± 0.12^{b}	9.45 ± 0.05^{b}	9.65 ± 0.09^{b}
Ash	0.50 ± 0.02^{d}	0.89 ± 0.01^{a}	0.79 ± 0.00^{b}	0.67 ± 0.02^{c}
Protein	11.22 ± 0.02^{a}	11.09 ± 0.08^{a}	10.94 ± 0.06^{ab}	10.70 ± 0.07^{b}
Lipid	0.55 ± 0.00^{b}	1.00 ± 0.04^{a}	0.65 ± 0.14^{b}	0.54 ± 0.01^{b}
Crude fiber	0.30 ± 0.07^{a}	0.49 ± 0.02^{a}	0.29 ± 0.02^{a}	0.39 ± 0.03^{a}
Apparent amylose	24.80 ± 0.02^{b}	25.50± 0.03^{a}	24.30 ± 0.01^{c}	24.35 ± 0.02^{c}
Cooking yield	211.43 ± 3.25^{c}	251.65 ± 4.80^{a}	231.10 ± 2.39^{b}	257.02 ± 5.47^{a}
Cooking time	15' 17"± 0.23^{c}	26' 31"± 0.10^{a}	22' 30" ± 0.24^{b}	26' 25"± 0.19^{a}
	BRS Sertaneja cultivar			
Characteristic	Milled rice	60°C for 250 min.	65°C for 180 min.	65°C for 420 min.
Moisture	11.63 ± 0.07^{a}	10.75 ± 0.02^{c}	10.50 ± 0.03^{d}	11.09 ± 0.04^{b}
Ash	0.56 ± 0.00^{c}	0.89 ± 0.03^{b}	0.94 ± 0.01^{a}	0.90 ± 0.01^{ab}
Protein	10.90 ± 0.12^{b}	11.07 ± 0.00^{b}	11.94 ± 0.01^{a}	11.98 ± 0.17^{a}
Lipid	0.59 ± 0.07^{b}	1.10 ± 0.01^{a}	1.00 ± 0.01^{a}	0.66 ± 0.10^{b}
Crude fiber	0.30 ± 0.02^{b}	0.43 ± 0.01^{a}	0.48 ± 0.02^{a}	0.44 ± 0.01^{a}
Apparent amylose	24.33 ± 0.78^{b}	24.65 ± 0.01^{a}	22.90 ± 0.80^{d}	23.62 ± 0.01^{c}
Cooking yield	213.51 ± 2.79^{b}	239.19 ± 5.15^{a}	238.35 ± 4.92^{a}	230.37 ± 3.52^{ab}
Cooking time	15' 50"± 0.06^{b}	26' 25"± 0.77^{a}	27' 39"± 0.82^{a}	24' 17"± 0.69^{a}

*Different letters in rows are significantly different by tukey's test ($p \leq 0.05$).

This fact could be related to the migration of these components from the peripheral layers to within the grain during the parboiling process, as already reported by Heinemann et al. (2005). Moreover, according to Amato and Elias (2005), the hydrothermal treatment allows the outer layers (which form the pericarp, tegument, the nucellus, and aleurone cells of the endosperm and part of the embryo, especially the scutellum) to be partially *loosened* and aggregated into the starchy endosperm of the caryopsis, so that the embryo remains in place, not easily detached during hulling, causing the increment observed in this study.

Besides that, the BRS Primavera cultivar had moisture content lower than that of BRS Sertaneja cultivar, perhaps because this variety produces finer grains and consequently the water displacement by diffusion has been faster during the drying process. Among the treatments selected, the treatment using the longer soaking time (420 min.) showed the highest moisture content. This result was expected, because water absorption increases with increasing soaking temperature and time (MIAH et al., 2002), also in function of the cooking characteristics (MARSHALL et al., 1993). Parboiled samples showed higher levels of mineral matter than white rice samples, which is consistent with results found by Heinemann et al. (2005). This is because in this process water-soluble minerals present in the outer layer of the grain (bran), migrate to the starchy endosperm, causing increased levels of these components (BHATTACHARYA; ALI, 1985). Another possibility would be related to the lower removal of minerals during the milling of parboiled rice in relation to white rice (WIMBERLY, 1983), since the grains resulting from the parboiling process had a more resistant physical consistency, and thus, the removal of minerals may be lower. Comparing the results for both cultivars, the BRS Primavera cultivar was more influenced by the soaking time than the BRS Sertaneja cultivar once the longer the soaking time, the greater the ash content, whereas for the BRS Sertaneja cultivar, the treatment with 420 min. did not differ from those using shorter times, perhaps by the fact that over 180 min., the constituents outside the grain no longer migrated to the starchy endosperm. For both cultivars, binary combinations of 58°C for 240 min. and 60°C for 250 min. respectively, showed no significant differences in protein content (Table 2) compared to white rice, which is consistent with data reported by Singh et al. (1999), in which the parboiling process had not caused significant changes in the rice protein content. The other treatments used for BRS Primavera have reduced the rice protein content. According to Amato et al. (2002), the reduced protein content in parboiled rice is either due to the difficulty of proteins to migrate (due to the size of molecules) or to the difficulty of solubilizing these proteins. Nevertheless, these levels may increase with increasing soaking time in the parboiling process, as shown in the treatment of BRS Sertaneja cultivar, which showed higher protein content than white rice. For the BRS Primavera cultivar, reduced protein content was found with increasing temperatures, probably due to denaturation, which reduces the solubility of proteins in grains. The proteins of BRS Sertaneja cultivar were more stable to denaturation, since this cultivar was subjected to the same temperatures and for longer soaking times without suffering a significant reduction in its content. According to Amato and Elias (2005), when starch gelatinization occurs, proteins are separated and submerged in the compact mass of gelatinized starch, which results in greater difficulty of extraction during milling. For parboiled rice samples, the lipid content increased in relation to milled rice sample; however, this difference was significant only in the treatment with temperature of 58°C for 240 min. using BRS Primavera cultivar, and in two treatments using BRS Sertaneja cultivar (60°C for 250 min. and 65°C for 180 min.). This behavior can be attributed to the fact that the grains resulting from this process became physically more rigid and more resistant to the removal of bran, consequently, a higher proportion of bran was preserved in outer layers, which showed higher abundance of these components. According to Bhattacharya and Ali (1985), there is no migration of lipids into the center of the endosperm during the parboiling process due to its hydrophobic characteristics. Therefore, the greater or lesser retention of these components probably depended on the MD. The fiber content of the starchy endosperm was not significantly changed for the BRS Primavera cultivar after hydrothermal treatments (Table 2). For Sertaneja BRS cultivar, a significant increase ($p < 0.05$) was detected in crude fiber, which could be associated to the contribution of resistant starch formed in grains during the parboiling process. The treatment that reached the highest amylose content in the BRS Primavera cultivar ($p < 0.05$) was the one using 58°C for 240 min. (Table 2), possibly due to the increased immersion time, which provides better separation between amylose and amylopectin during the analytical determination. The BRS Sertaneja cultivar showed differences ($p > 0.05$) in all samples in relation to the amylose content (Table 2). The variation in amylose content does not affect the rice nutritional value; however, it greatly influences the cooking quality, so that, the higher the amylose content, the drier and more separated the grains will be after cooking (GONZALES et al., 2004). All samples showed intermediate amylose content, i.e., the grains tended to be loose and soft after cooking. Raghavendra and Juliano (1970) reported that the amylose content in rice is not modified by the parboiling process and changes in the texture of cooked parboiled rice, such as increased hardness, seem to be related to the higher adhesion / cohesion of the endosperm starch granules, which can influence the solubility of starch and proteins in the cooking water.

Cooking test

Parboiled rice samples of the BRS Primavera cultivar have differed ($p < 0.05$) from white rice samples as for the cooking yield. The sample subjected 65°C for 60 min. exhibited the highest milling degree (8.9 g 100 g^{-1}) when compared with the other samples selected for the cooking test, and the highest cooking yield when compared with the sample subjected to temperature of 60°C for 112 min. (Table 2). According to Mohapatra and Bal (2006), the hydration rate increases progressively with the milling degree (above 6 g 100 g^{-1}), especially for thinner grains, since a higher removal of the bran layer allows the starch granules to absorb higher amounts of water and expand more naturally during cooking. The treatment with the lowest yield cooking (60°C for 112 min.) was not the one showing the lowest milling degree (6.9 g 100 g^{-1}), but rather that with the lowest apparent amylose content (24.3 g 100 g^{-1}). In agreement with Champagne et al (2004), apparent amylose has a positive correlation with grain swelling, since the amylose content improves the ability of the starch granules to absorb water and expand. For the BRS Sertaneja cultivar, the sample subjected to 65°C for 420 min showed the lowest cooking yield and the lowest MD, and therefore absorbed less water during cooking due to the higher bran content remaining after milling. The highest cooking yield was obtained for the sample subjected to 60°C for 250 min, also showing the highest MD (8.9 g 100 g^{-1}) and apparent amylose content (24.7 g 100 g^{-1}), among those selected. Comparing the results obtained for both cultivars, the BRS Sertaneja cultivar showed lower cooking yield, since it is a thicker cultivar, and even being subjected to a greater milling degree, it requires more time for starch granules to absorb water and gelatinize, increasing thus the grain size and hence the cooking yield. Rice samples differed ($p < 0.05$) from white rice samples, showing longer cooking times (Table 2). According to Mohoric et al. (2009), the endosperm of the parboiled rice has a more compact starch structure and the reduced porosity of the grains generally increases the cooking time. Moreover, according to Vidal et al. (2007), the size and shape of the endosperm (mainly thickness) are probably the most important factors affecting the cooking time; however, rice with high ash content also showed long cooking time. The cultivars studied showed an elongated shape, with little difference in length, thickness and width of the grains, but the cultivar BRS Primavera was smaller (0.75 cm) and thinner (0.16 cm) than the cultivar BRS Sertaneja (0.77 and 0.18 cm, respectively). In this study, the water diffusivity in the BRS Primavera cultivar may have been higher (faster water absorption during cooking) due to smaller grain thickness, which showed an average cooking time of 25'14", while the BRS Sertaneja cultivar showed average time of 26'12". For cooking purposes, the cooking test was valid because it reproduces the rice cooking profile that will be obtained in real situations; however, it does not always correlate with physical and chemical tests (amylose content, gelatinization temperature).

Sensory analysis

The results of the acceptance test are listed in Table 3. For attribute appearance, the evaluators perceived differences between samples, but without consensus among them, i.e., there were differences in responses for the attribute examined, and there may be evaluators who liked or disliked the parboiled rice appearance. However, most mean scores obtained was among categories 'from liked slightly to liked moderately', confirming the acceptance for rice with loose appearance.

Table 3. Means and standard deviations of scores for appearance, aroma, flavor and texture of cooked parboiled upland rice samples of BRS Primavera and BRS Sertaneja cultivars obtained in the acceptance test

	BRS Primavera cultivar		
Attribute*	58°C for 240 min.	60°C for 112 min.	65°C for 60 min.
Appearance	6.38 ± 1.51^{b}	7.20 ± 1.40^{a}	6.78 ± 1.59^{ab}
Aroma	5.88 ± 1.79^{a}	6.48 ± 1.46^{a}	6.08 ± 1.75^{a}
Flavor	6.34 ± 1.72^{a}	6.58 ± 1.49^{a}	6.54 ± 1.53^{a}
Texture	6.20 ± 1.75^{b}	6.76 ± 1.25^{ab}	6.90 ± 1.28^{a}
	BRS Sertaneja cultivar		
Attribute*	60°C for 250 min.	65°C for180 min.	65°C for 420 min.
Appearance	6.36 ± 1.59^{a}	5.80 ± 1.91^{b}	6.60 ± 1.39^{a}
Aroma	5.68 ± 1.73^{a}	5.88 ± 1.73^{a}	6.06 ± 1.67^{a}
Flavor	5.86 ± 1.63^{a}	5.74 ± 1.65^{a}	6.06 ± 1.79^{a}
Texture	6.42 ± 1.72^{a}	6.46 ± 1.39^{a}	6.64 ± 1.43^{a}

*Means with different letters in the same row are significantly different by Tukey's test ($p \leq 0.05$).

With regard to the attribute of aroma, the evaluators have not perceived differences between samples and there was no consensus among them. For this attribute, it was observed that the parboiling process left a characteristic odor. According to Amato et al. (2002), this is due to hull components that were transferred to the grain. For the flavor of both cultivars, the evaluators have not perceived differences between the samples tasted and there was no consensus among them, while for the texture of BRS Primavera samples, the evaluators have perceived differences, and there were tasters who liked and who did not like the parboiled rice texture. For the BRS Sertaneja cultivar, evaluators have not perceived differences between samples. Texture ranged from soft to extremely soft according to the cooking test. Whereas samples were accepted with scores from all the attributes above 6.0, BRS Primavera cultivar was accepted when processed at 60°C for 112 min. and 65°C for 60 min. of soaking, while BRS Sertaneja cultivar was only accepted with soaking at 65°C for 420 min.

Conclusion

The higher the temperature used in the soaking, the lower the milling degree and consequently the higher head yield. The parboiled rice of BRS Primavera cultivar revealed higher ash and lipid contents in relation to milled rice, while BRS Sertaneja showed higher ash, crude protein, lipid and crude fiber contents. The parboiled rice of both cultivars presented longer cooking time and higher yield than milled rice samples. The condition of soaking at 65°C for 60 min. and 60ºC for 112 min. was enough for the acceptance of all sensory attributes evaluated in BRS Primavera, and 65ºC for 420 min. in BRS Sertaneja.

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