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Características físico-químicas, cozimento e textura de arroz polido e integral de diferentes variedades comercializadas no Brasil

Physico-chemical, cooking and texture characteristics of polished and whole rice grain of different varieties marketed in Brazil

Características fisicoquímicas, cocción y textura de arroz pulido y integral de diferentes variedades vendidas en Brasil

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Resumo

As diversidades de arroz integral de pericarpo preto e vermelho têm sido valorizadas no Brasil devido às diferentes características de cor, textura e também pela associação com benefícios à saúde. Esse trabalho teve como objetivo avaliar as características físico-químicas, de cozimento e textura de amostras de arroz polido e integral de diferentes variedades comercializadas no Brasil. Foi realizada uma amostragem exploratória e aleatorizada, objetivando adquirir o maior número de marcas, sendo coletadas 28 amostras e divididas em 6 grupos: arroz branco polido, arroz branco parboilizado polido, arroz branco integral, arroz vermelho integral, arroz preto integral e arroz selvagem integral. Foram analisados os teores de umidade, proteína, cinzas, minerais, dureza e adesividade. A qualidade de cozimento foi avaliada através da determinação do tempo de cozimento, índice de absorção de água e índice de expansão. Foi observada uma forte correlação entre o teor de proteína e o valor de dureza dos grãos cozidos. As amostras de arroz polido apresentaram os menores valores de cinzas e minerais e menor tempo de cozimento. Foi observada uma forte correlação entre o índice de expansão e o valor de dureza das amostras cozidas. Os resultados obtidos contribuem para uma melhor compreensão da qualidade do arroz comercializado no Brasil e demonstram uma grande variação entre as amostras em termos de propriedades físico-químicas, cozimento e textura.

Palavras-chave: *Oryza sativa*; *Zizania aquática*; Grãos de cereais; Grão integral; Arroz selvagem.

Abstract

The diversity of whole rice grains with black and red pericarp has been valued in Brazil due to its different characteristics of color, texture, and also due to the association with health benefits. This work aimed to evaluate the physicochemical, cooking, and textural characteristics of different samples of polished and whole rice grains from different varieties marketed in Brazil. An exploratory and random sampling was carried out, aiming to obtain the largest number of brands, being collected 28 samples, and divided into 6 groups: polished white rice, white polished parboiled rice, whole white rice, whole red rice, whole black rice, and whole wild rice. Moisture content, crude protein, ash, mineral content, hardness, and adhesiveness were analyzed. The cooking quality was evaluated through the determination of cooking time, swelling ratio, and volume expansion ratio. A strong correlation between the protein content and the hardness value of cooked grains was observed. The polished samples showed the lowest ash and mineral values and the shortest cooking time. A strong correlation was also observed for the volume expansion ratio and hardness of cooked samples. The data obtained contribute to a better understanding of the quality of the rice marketed in Brazil and demonstrate a considerable variation among samples in terms of physicochemical, cooking, and texture properties.

Keywords: *Oryza sativa*; *Zizania aquatic*; Cereal grains, Whole grain; Wild rice.

Resumen

La diversidad del arroz integral con pericarpio negro y rojo se ha valorado en Brasil debido a las diferentes características de color, textura y también por la asociación con los beneficios para la salud. El objetivo de este trabajo fue evaluar las características físico-químicas, de cocción y de textura de muestras de arroz pulido y integral de diferentes variedades vendidas en Brasil. Se realizó un muestreo exploratorio y aleatorizado, con el objetivo de adquirir el mayor número de marcas. Se recolectaron 28 muestras y se dividieron en 6 grupos: arroz blanco pulido, arroz blanco precocido, arroz integral blanco, arroz integral rojo, arroz integral negro y arroz integral silvestre. Se analizaron los contenidos de humedad, proteínas, cenizas, minerales, dureza y adhesividad. La calidad de cocción se evaluó determinando el tiempo de cocción, el índice de absorción de agua y el índice de expansión. Se observó una fuerte correlación entre el contenido de proteína y el valor de dureza de los granos cocidos. Las muestras de arroz pulido mostraron los valores más bajos de cenizas y minerales y el tiempo de cocción más corto. Se observó una fuerte correlación entre el índice de expansión y el valor de dureza de las muestras cocidas. Los resultados obtenidos contribuyen a una mejor comprensión de la calidad del arroz vendido en Brasil y demuestran una gran variación entre las muestras en términos de propiedades físico-químicas, cocción y textura.

Palabras clave: *Oryza sativa*, *Zizania aquatica*, granos de cereales, granos integrales, arroz silvestre.

1. Introduction

Cereal grains are the principal component of the human diet, and rice (*Oryza sativa*) is especially important for food security because it is a staple food and primary source of carbohydrates and energy for different populations worldwide (FAO, 2014). Besides, it is an essential source of fiber, minerals, vitamins, and other beneficial health biomolecules (Sen et al., 2020).

From the processing of the rice grains, the lignocellulosic husk is removed and obtained the whole rice, composed by 4.8% of dietary fiber and source of phytochemicals with potential health benefits, mostly present in the bran fraction (Shao & Bao, 2019). The preference for polished grains by consumers is due to their culinary characteristics, such as the highest cooking yield, faster cooking time, and softer texture when compared to whole grains (Puri et al., 2014).

In terms of quality for consumption, these culinary characteristics directly influence the purchase and use of the product, especially those related to the grain texture (Bergman, 2019). Rice grain texture can be evaluated both by sensory methods with consumers or using instrumental methods. The texture analyzer has the advantages of excellent precision and reproducibility, with simpler and faster analysis (Bhat & Riar, 2016).

Recently, the diversity of rice with black and red pericarp has been valued in Brazil due to its different characteristics of color, texture, and flavor. Such varieties have higher antioxidant activity due to the presence of polyphenols in high concentrations (Sompong et al., 2011). However, despite the good acceptance in the Brazilian market, its consumption is still inexpressive when compared to the polished white rice (CONAB, 2015).

The "wild rice" (*Zizania aquatica*) is another cereal that has been valued, especially in gastronomy. Wild rice belongs to the Poaceae family, but, as it pertains to another species, it is not technically classified as rice; however, wild rice is the most used name in Brazil for its identification and marketing. When compared to the polished white rice, wild rice has higher protein (14.7%), dietary fiber (6.2%), and lower lipid content (1.1%), with antioxidant activity around 10–15 times higher (Timm & Slavin, 2014).

Few studies have been carried out, aiming to characterize the quality of colored pericarp rice in Brazil. Knowing such nutritional and technological properties is a way of commercially valuing these foods, as well as popularizing their consumption. In this way, the present work aimed to evaluate the physicochemical, cooking, and textural characteristics of different samples of polished and whole rice grains of the white, red, black, and wild varieties marketed in Brazil, as well as to verify the correlation among the parameters evaluated.

2. Materials and Methods

An exploratory and random sampling was carried out, aiming to obtain the largest number of rice varieties, being collected a total of 28 samples containing at least 250 g of grains. Samples were acquired in the consumer market of the metropolitan region of Belo Horizonte, Minas Gerais, Brazil, and, also, from online stores. The samples were separated into 6 groups: polished white rice (PW: *n* = 5), white polished parboiled rice (PP: *n*= 5), whole white rice (WW: *n* = 5), whole red rice (WR: n = 5), whole black rice (WB: n = 4) and whole wild rice (WWR: n = 4). Figure 1 illustrates the groups of rice evaluated.

Figure 1 - Different varieties of rice analyzed. A- polished white rice; B- white polished parboiled rice; C- whole white rice; D- whole red rice; E-whole black rice; F-whole wild rice.

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2.1 Physicochemical analysis

For physicochemical determinations, samples were quartered manually and grounded in a household mill (PHILIPS WALITA RI7761). The analysis was performed in triplicates, according to AACC Approved Methods of Analysis (1999), as follows: moisture content (method 44-19.01), crude protein (method 46-12.01), and ash content (method 08-01.01). Ash samples were used to determine the mineral composition (Ca, Mg, Mn, Fe, Zn, Cu, Co, Cd, Li, Ba, and Cr) by atomic absorption spectrometry (AAS) using a Hitachi-Z8200 model spectrometer coupled to a Hitachi graphite furnace. The samples were prepared and analyzed according to the AOAC method 968.08 (AOAC, 2000). Colorimetric analysis was performed using a digital colorimeter CR 400 (Konica Minolta, Japan) with a CIELAB system (L*a*b* scale).

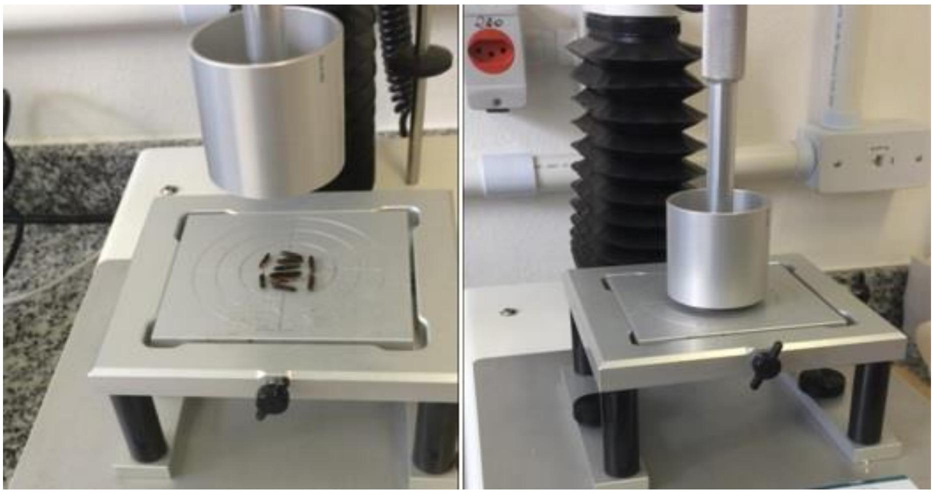
2.2 Cooking quality parameters

The cooking time (CT), swelling ratio (SR), and volume expansion ratio (VER) were determined in triplicates, as described by Bergman (2019). Samples of 25 g were cooked in excess of water in stainless steel until the endosperm presented starch gelling. CT was verified pressing 10 grains between 2 glasses until at least 90% has no longer an opaque center. The time at which the opaque central core just disappeared was recorded as CT (min). SR was expressed as g of cooked rice per gram of uncooked rice, and VER was expressed as mL of cooked rice/mL of uncooked rice.

2.3 Texture characteristics

The hardness and adhesiveness were evaluated using the TA.XT^{plus} texture analyzer (Stable Micro Systems), according to the method proposed by Carvalho et al. (2015), using a P/50 cylindrical probe, uniaxial compression, pre-test speed of 2 mm/s, test speed of 0.5 mm/s, post-test speed of 0.5 mm/s, return distance equal to 5 mm and 95% deformation (sample was subjected to compression up to 95% of the initial height). Data were obtained using Exponent Lite software version 5.1.1.0, licensed to UFSJ. Figure 2 demonstrates the disposition of the grains during compression.

Figure 2 - Evaluation of the texture (hardness and adhesiveness) of cooked rice grains using a texture analyzer.



Source: The Authors.

2.4 Statistical analysis

Data were evaluated by descriptive statistics, Shapiro-Wilk test, ANOVA and Tukey test, at 5% probability level, using Sisvar 5.0 software. To verify the existence of a correlation among the parameters evaluated Pearson's Coefficient was calculated using Microsoft Excel software.

3. Results and Discussion

3.1 Physicochemical composition and color of uncooked grains

Moisture is one of the main factors that affect the quality of rice grains during storage and distribution. In the present study, the moisture content ranged from 6.8 ± 0.6% to 10.4 ± 0.7%. All samples were under the maximum limit of 14%, regulated by the Brazilian legislation (BRASIL, 2009). The lowest values ($p < 0.05$) were observed in WWR samples, as shown in Table 1.

Table 1 - Mean values ± standard deviation of physicochemical and color evaluations of uncooked rice grains from different varieties.

Samples*	Moisture content (%)	Protein (%)	Ash content (%)	Color L*	Color a*	Color b*
PW	9.8 ± 0.3[ab]	5.44 ± 0.83[b]	0.31 ± 0.27[b]	70.5± 2.3[a]	-0.53 ± 0.18[d]	10.2 ± 0.7[b]
PP	10.4 ± 0.7[a]	4.47 ± 0.39[b]	1.21 ± 0.55[a]	64.6± 3.7[ab]	-0.76± 0.35[d]	20.2± 1.2[a]
WW	8.2 ± 1.4[b]	3.38 ± 0.24[b]	1.36 ± 0.08[a]	57.7 ± 3.8[b]	3.12 ± 0.34[b]	23.2 ± 1.7[a]
WR	10.0 ± 0.7[ab]	5.50 ± 0.80[b]	1.34 ± 0.39[a]	43.0 ± 1.2[c]	13.43 ± 3.81[a]	22.7 ± 4.4[a]
WB	9.6 ± 0.2[ab]	3.95 ± 1.01[b]	1.55 ± 0.13[a]	19.9 ± 1.5[d]	3.91 ± 1.68[b]	2.9 ± 1.4[c]
WWR	6.8 ± 0.6[c]	9.43 ± 0.78[a]	1.68 ± 0.12[a]	20.9 ± 1.2[d]	1.95 ± 0.38[c]	4.9 ± 1.1[c]

*PW: polished white rice, PP: white polished parboiled rice; WW: whole white rice; WR: whole red rice; WB: whole black rice; WWR: whole wild rice.
Fonte: Autores

The protein content varied from 3.38 ± 0.24 g to 9.43 ± 0.78 g and, the highest values ($p < 0.05$) were found in WWR samples. Surendiran et al. (2014) reported that this type of grains (*Zizania* spp.) has high protein content, ranging from 10-18%, which is composed of about 80% glutelins, 10% globulins, 10% albumins and, to a lesser extent, prolamins (1%).

As showed by Fitzgerald (2010), high protein values in rice can affect some texture attributes of cooked grains, such as higher values of hardness and less amount of water required to cook. In the present study, a strong correlation ($r = 0.7151$) between high protein content and the high hardness value of cooked grains was observed. However, no other relationship between the protein content and cooking parameters was observed.

The rice protein has drawn scientific and industrial interest in recent years because it is a component generally considered hypoallergenic. Thus, samples with higher protein content can be used for protein extraction to prepare food products based on vegetable protein (Amagliani et al., 2017).

The ash content ranged from 0.31 ± 0.27% in the PW samples to 1.68 ± 0.12% in the WWR samples. The lowest value was found in PW samples, which differed ($p < 0.05$) from the other groups. Ash content in PW samples was expected to be the lowest among the samples evaluated since the minerals are present mainly in the bran, and this fraction is removed after the polishing (Bergman, 2019). Table 2 shows the results of minerals quantified in the samples.

Table 2 - Mineral levels (mean values ± standard deviation) found in uncooked rice grains from different varieties.

Samples*	Mineral level (mg/Kg) b.u.					
	Ca	Mg	Mn	Fe	Zn	Cu
PW	43.70±25.9^{b}	137.24±101.8^{b}	6.74±3.9^{c}	1.32±0.84^{c}	7.64±3.8^{bc}	1.16±0.55^{b}
PP	38.91±27.3^{b}	205.90± 72.9^{b}	5.66±2.43^{c}	2.19±1.69^{bc}	5.43±1.44^{c}	1.87±0.72^{b}
WW	171.57±97.5^{a}	1001.16±190.7^{a}	22.02±7.0^{a}	7.21±3.03^{ab}	13.74±4.1^{bc}	1.91±0.30^{b}
WR	149.84±12.8^{a}	1054.4±397.5^{a}	21.24±1.7^{ab}	9.42±2.10^{a}	21.0±2.57^{b}	3.7±1.58^{ab}
WB	157.4±51.4^{a}	1129.46±151.87^{a}	26.83±12.9^{ab}	10.02±1.61^{a}	18.69±2.5^{bc}	4.77±1.27^{ab}
WWR	100.85±61.9^{a}	882.17±338.84^{a}	11.28±4.01^{bc}	11.13±6.03^{a}	43.20±18.5^{a}	6.08±4.86^{a}

*PW: polished white rice, PP: white polished parboiled rice; WW: whole white rice; WR: whole red rice; WB: whole black rice; WWR: whole wild rice.
Fonte: Autores

Minerals Ca, Mg, Mn, Fe, Zn, and Cu were quantified in all samples, while Co, Cd, Li, Ba, and Cr were not identified in quantifiable concentrations (data not shown). In general, the PW and PP samples showed the lowest values of minerals among the groups evaluated. Hansen et al. (2012) demonstrated that frictional polishing, similar to that of commercial mills, reduced the concentration of Fe, Mg, P, K and Mn by 60–80% in different rice genotypes, which explains the lower levels found in the polished samples analyzed in the present work.

The presence of minerals in the samples demonstrate the importance of this food to maintain a balanced diet and regular metabolic functions. Despite variations from polished and unpolished samples, all varieties of rice analyzed represent a rich source of minerals, such as calcium, iron, magnesium, manganese, and zinc. The variations in results among samples from the same group may also occur due to the different rice genotypes, and agronomic and cultivation conditions (Reddy et al., 2017).

About color, the values presented in Table 1 demonstrate that WB and WWR samples had fewer values ($p < 0.05$) of L*, demonstrating that these samples are darker than the other varieties, while PW was the lightest. WR showed the highest value of a*, indicating higher red color among the groups evaluated. The red and black color of the pericarp is the main characteristic that visually differentiates them from traditional white varieties, mainly due to the accumulation of phenolic compounds. In black rice, anthocyanins are found in higher

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quantities among samples of the colored pericarp, in total concentrations of up to 244.45 mg/100 g, as reported by Ponnappan et al. (2017).

Sompong et al. (2011) found that the color of dark red rice is due to the anthocyanins cyanidin-3-glucoside and peonidin-3-glucoside, with concentrations ranging from 19.4 to 140, 8 mg/100 g (d.b.) and 11.1 at 12.8 mg/100 g, respectively. In wild rice, anthocyanins and proanthocyanidins are present in insignificant amounts. On the other hand, this grain has a high protein and low lipid content in relation to *Oryza sativa* spp. grains (Massaretto et al. 2013).

3.2 Cooking and texture attributes of rice quality

The shortest cooking times were observed in PP and PW samples, as shown in Table 3. The longest CT was observed for WWR samples (44.0 ± 1.5 min), which did not differ from WW rice. Due to the high fiber content present in the pericarp of whole grains, water absorption is slower (Bergman, 2019), which justifies the longest CT in the whole samples evaluated in the present study.

Table 3 - Cooking and texture characteristics of cooked grains from different rice varieties.

Samples	CT (min)	SR	VER	Hardness (g)	Adhesiveness (g.sec^{-1})
PW	30.0 ± 1.6^{c}	3.78 ± 0.37^{a}	4.36 ± 0.78^{a}	116.3±16.1^{b}	-21.7± 4.7^{b}
PP	27.5 ± 1.7^{c}	3.18 ± 0.35^{b}	3.55 ± 0.16^{ab}	148.9± 13.0^{b}	-22.7± 2.7^{b}
WW	41.0 ± 3.4^{ab}	3.02 ± 0.49^{b}	3.86± 0.65^{a}	141.2±32.3^{b}	-14.8± 13.9^{ab}
WR	45 ± 6.9^{a}	3.41 ± 0.28^{a}	4.16 ± 3.69^{a}	3788.6± 18.1^{b}	-22.0±13.2^{b}
WB	37.5 ± 1.4^{b}	2.52 ± 0.59^{c}	3.16 ± 0.20^{b}	113.9±13.8^{b}	-26.6±6.40^{b}
WWR	44.0 ± 1.5^{a}	1.97 ± 0.53^{d}	2.75 ± 0.11b^{c}	248.3± 39.3^{a}	-0.21± 0.06^{a}

* PW: polished white rice, PP: white polished parboiled rice; WW: whole white rice; WR: whole red rice; WB: whole black rice; WWR: whole wild rice.

Fonte: Autores

According to Paraginski (2014), the parboiling process increases the cooking time of the grains because the water absorption is slower due to partial starch gelling. However, the water absorption at the end of cooking is higher. Such behaviors were not observed in the

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present study, probably because several brands of the same variety were analyzed, making the sampling more heterogeneous and with a considerable variation.

The lowest SR was observed for WWR samples, differing ($p < 0.05$) from all other varieties. The highest values were found for PW and WR samples. The WR sample had the lowest values for VER, while all the others showed no differences among them ($p<0.05$). Data were similar to those reported by Bhat and Riar (2019) for 12 different rice cultivars from India, with wide variation among samples.

The VER is indicative of rice texture, and, as described by Bhattacharya (2011), the higher the VER, the lower the hardness value. A strong correlation was observed ($r = 0.7203$) for these parameters, demonstrating that samples with higher VER, such as PW, PP, WW and WR presented lower values of hardness, while samples with lower VER (BR and WR) presented the highest hardness values. For the adhesiveness, no correlation was observed with other parameters. WWR samples had the highest hardness, and, according to Tikapunya, Henry and Smyth (2018), these characteristics of texture, as well as its flavor and aroma, can differentiate this rice from other varieties and may even be more valued in sensory terms.

4. Final considerations

All samples were under the maximum limit of 14% for moisture content, regulated by the Brazilian legislation. The highest values of protein were found in WWR samples. A strong correlation between high protein content and the high hardness value of cooked grains was observed. The mineral content had a large variation between polished and unpolished samples, and the whole samples had the highest cooking times. Samples with higher VER presented lower values of hardness. These data demonstrate that the quality of the rice grains marketed in Brazil has a considerable variation among samples. Even the samples grouped by varieties are heterogeneous in terms of physicochemical composition, cooking, and texture attributes. The results contribute to a better understanding of the quality of the rice marketed in Brazil, mainly concerning samples with red and black pericarp.

Due to the nutritional and technological characteristics of the different rice varieties evaluated in this research, it is suggested new investigations aiming to explore such whole foods in the development of new products, especially those with colored pericarp, to popularize and increase the consumption of such cereals still little valued by consumers in Brazil.

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