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Comparison between Varieties of Rice (*Oryza sativa* L.) Produced in Portugal—Mineral and Quality Analysis †

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Abstract: Rice (*Oryza sativa* L.) is considered one of the most consumed cereals worldwide. In fact, for most countries, it is considered a staple food crop. In this context, in Portugal, Ariete and Ceres are well known as varieties that produce grains with a high quality, yet little is known about their nutrient accumulation. In this context, this study aims to characterize and compare both varieties produced in the central region of Portugal (Salvaterra de Magos-Ribatejo). Whole and white rice grains, as well as their respective flours, were analyzed in order to quantify the mineral content of macro- and microelements (Mo, Ca, K, P and S). Molybdenum (Mo) content varied significantly between 4.7–11.2 $mg \cdot kg^{-1}$ in the whole flour of Ceres and Ariete, respectively, while P content was only detected in the flour of the Ariete variety. Regarding both varieties, concerning the other elements, there were no significant differences in their content. Moreover, the total ash content in the refined flour showed significant differences in both varieties. Quality parameters such as the density of the grains and colorimetric indexes (L, a* and b*) in brown and white grain were also considered, and it was found that density values varied between 1301–1651 kg/m^3 (in the Ariete variety) and 1492–1573 kg/m^3 (in the Ceres variety). It was concluded that, in spite of the differences found in both varieties, minerals contents, combined with the quality parameters, showed common characteristics required for high industrial and gastronomic potential.

Keywords: Ariete variety; Ceres variety; mineral contents; quality analysis

1. Introduction

Considered a staple food for nearly two-thirds of the world's population, rice (*Oryza sativa* L.) is referenced as the second most cultivated and consumed cereal crop in the world [1]. European countries produce 4.5 million tons of paddy rice, which translates into a self-sufficiency rate of about 65%. Although the Portuguese are the main consumers in Europe (15 kg per capita per year), Portugal contributes 6% (190,000 tons of paddy rice) to European production [1–3]. In Portugal, rice is mainly produced in the Lisboa and Vale do Tejo region (47%), Ribatejo [4]. Commercially known as Carolino rice, it is botanically classified as ssp. *japonica*. Being well adapted to Portuguese environmental conditions, this type of rice is widely used in traditional gastronomy [3]. Moreover, it is self-sufficient in the consumption of Carolino rice; however, it only covers approximately 75% of the national need [3]. Thus, it is the most widely produced type of rice in the different regions of Portugal. The Ariete variety (the Carolino rice-type) stands out as the most widely grown in Portugal (21% of the total varieties grown) [5]. It is a variety of Italian origin of the long A-type (Carolino), and has been cultivated in Portuguese soils for about 30 years. It is a reference variety for Carolinos, with high industrial yield, and is appreciated by farmers and industrialists for its quality and regularity of production [5]. The Ceres variety emerged from the need for modern and national varieties of rice to differentiate this area. It is a Portuguese variety of Carolino rice, long type-A, which results from crossbreeding performed under the National Program for Genetic Improvement of Rice and partnerships with many other entities for more than 10 years [6]. Characteristics such as good phytosanitary behavior, a completely glassy grain, and excellent gastronomic quality, make this variety stand out [7]. In this context, in Portugal, Ariete and Ceres are well known as varieties that produce grains of high quality, yet little is known about their nutrient accumulation.

Considering the importance of the rice varieties, Ariete and Ceres, produced in the central region of Portugal (Ribatejo), this work aims to characterize these varieties while evaluating the mineral content and quality of the grains.

2. Materials and Methods

2.1. Experimental Fields

This study was carried out in a paddy rice (*Oryza sativa* L.) field (coordinates 39°02′21.8″ N, 8°44′22.8″ W) located in the middle of the lezíria ribatejana (Ribatejo, Portugal), at the experimental station of the Rice Technological Center (COTArroz). Two rice varieties, Ariete and Ceres, were used as a test system. The trial duration was between 30 May to 2 November 2018. The production of fertilizers; the control of diseases, insect pests, and weeds; and water management are the typical applications of the paddy rice crop in Ribatejo. The accurate characterization of some parameters such as the climate of the studied area, irrigation water, and soil characteristics were also taken into account and described in previous work [8]. In Ariete and Ceres varieties, the analysis occurred in brown and white rice grains and flours, respectively. In brown rice, only the husk was removed; however, in white rice, the husk, bran, and germ were removed.

2.2. Quantification of Macro- and Microelements

The mineral contents of macro- and microelements in whole and refined flour were determined using an XRF analyzer (model XL3t 950 He GOLDD$^+$) under a He atmosphere [9].

2.3. Quality Parameters: Ash Content, Density, and Colorimetric Parameters

To determine the percentage of ash content, we followed the methodology described by [10]. The whitened flour samples were weighed (5 g) into crucibles and then burned in a muffle at 550 °C for 5 h. After that time, the crucibles were placed in an excicator until they reached a constant weight, according to the method used, and then weighed. Grains were hulled and whitened, as described by [11]. For each variety, 1000 grains were picked and weighed, adopting the methodology described by [8]. Density was calculated based on the weight and volume of the brown and white rice grains. Determination of the colorimetric parameters followed the methodology of [12] in brown and white rice grains.

2.4. Statistical Analysis

Data were statistically analyzed using a One-Way ANOVA ($p \leq 0.05$), to assess differences among varieties. Based on the results, a Tukey's test for mean comparison was performed, considering a 95% confidence level. Different letters indicate significant differences among the different treatments of each variety. Statistical analysis was performed using the IBM SPSS Statistics (version 20) program.

3. Results

3.1. Macro- and Microelement Content

In the brown flours of the different varieties, there were significant differences, and the Mo content ranged from 4.69–11.2 mg·kg^{-1} (Table 1). Comparing the refined flours of the different varieties, P contents were only detected in the Ariete variety. In this variety, Mo, K, and P content were significantly lower in the refined flour, while in the Ceres variety, only Mo content was not affected by industrial processing.

Table 1. Average values (mg·kg^{-1}) ± standard deviation (n = 4) of Mo, Ca, K, P, and S in the whole (WF) and refined flours (RF) of *Oryza sativa* L. varieties Ariete (AR) and Ceres (C) at harvesting. Different letters indicate significant differences between varieties in the same flour (letters a and b) and between different flours in the same variety (letters A and B) ($p \leq 0.05$).

Treatment		Mo	Ca	K	P	S
WF	AR	11.2 ± 0.19 aA	103 ± 13.4 aA	2750 ± 237 aA	1962 ± 263 aA	1054 ± 52.9 aA
	C	4.69 ± 0.21 bA	211 ± 29.2 aA	4181 ± 433 aA	2603 ± 385 aA	1371 ± 96.5 aA
RF	AR	5.46 ± 0.17 aB	53.6 ± 2.87 aA	1010 ± 35.7 aB	86.4 ± 8.30 aB	939 ± 13.5 aA
	C	5.30 ± 0.18 aaA	57.4 ± 2.60 aB	859 ± 49.6 aB	<65.0 bB	910 ± 18.8 aB

3.2. Ash Content

Considering the ash contents (Figure 1), the Ariete variety showed slightly higher values (2.45%) compared to the Ceres variety (1.88%).

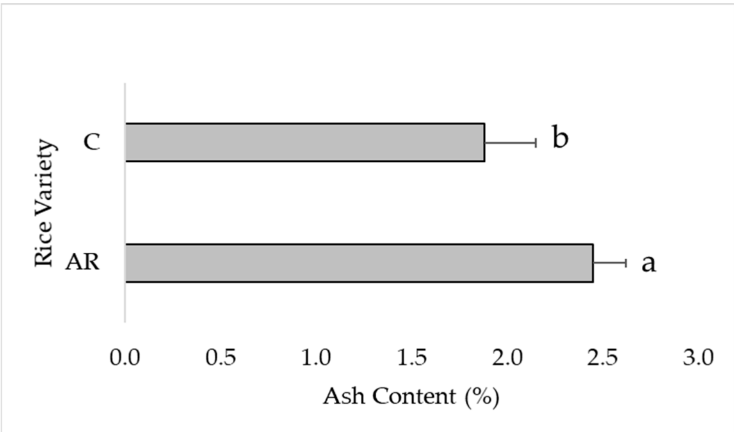


Figure 1. Average values (%) ± standard deviation (n = 4) of ash content in the refined flours of *Oryza sativa* L. varieties Ariete and Ceres at harvesting. Letters a and b indicate significant differences among varieties ($p \leq 0.05$).

3.3. Density and Colorimetric Analysis

Regarding density, values ranged between 1301–1651 kg/m^3 in the Ariete variety (Figure 1). In the Ceres variety, the minimum value registered was 1492 kg/m^3 and the maximum was 1573 kg/m^3 (Figure 2). There were significant differences between brown with white grains in the Ariete variety, while in the Ceres variety, these differences were not so evident. In the Ariete variety, the density of the white grains was significantly higher than in the brown grains.

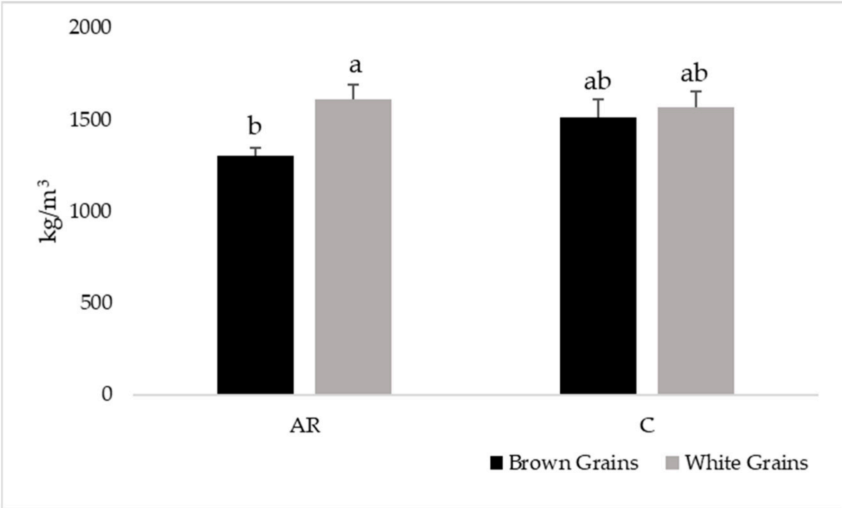
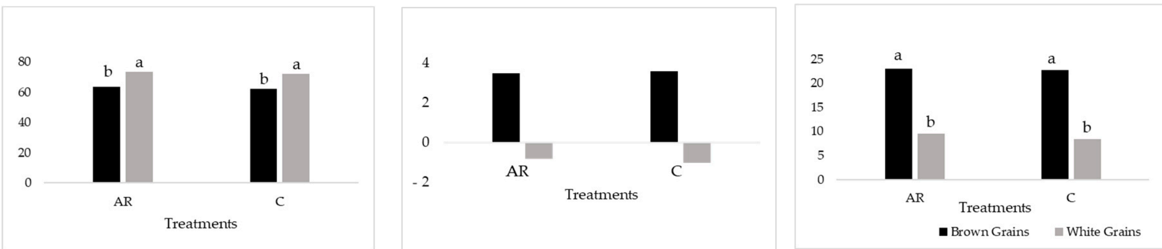


Figure 2. Average (kg/m^3) ± standard deviation (n = 4) density of brown and white rice grains of *Oryza sativa* L. varieties Ariete (AR) and Ceres (C) at harvesting. Letters a and b indicate significant differences among grains in each variety ($p \leq 0.05$).

In each variety, L, a*, and b* values show significant differences, and it can be observed that it is extensive between brown and white rice grains (Figure 3). The L of the samples was high (greater than 50%) in both varieties. Regarding the a* parameter, the colors red and green were evidenced in brown and white rice grains, respectively. The yellow color, corresponding to the b* parameter, was evident in both treatments.



(I) (II) (III)

Figure 3. Average colorimetric parameters ± standard deviation (n = 4) of brown and white rice grains of *Oryza sativa* L. varieties Ariete (AR) and Ceres (C) at harvesting. Labels (**I**), (**II**), and (**III**) represent L*, a*, and b* parameters, respectively. Letters a and b indicate significant differences among grains in each variety ($p \leq 0.05$).

4. Discussion

In Portugal, rice is historically considered a very important crop that is widely consumed [1]. Portugal has characteristics that allow for the cultivation of Carolino rice with unique features [6]. Based on increasing agricultural production, the maintenance of soil health, and environmental sustainability, strategies have been developed for the creation of Portuguese varieties capable of meeting the needs of the farmers/the industry; this means they can produce differentiated rice of great quality that the consumer values, but that is still accessible at a competitive price [6,13], such as the Ceres variety. This variety achieved characteristics that other varieties could not, namely good yields, long grains that do not break much in industrial processes, and fabulous gastronomic potential—these are quality Carolino grains [6]. Mineral micronutrients are essential for metabolism, and worldwide, their deficiency is associated with human health problems [14,15]. Humans obtain these micronutrients from their diet, and considering that rice is a major cereal crop and one of the top three commodities in terms of food safety, it is important to perform quality control analyses such as contaminant identification [3]. This fact justifies the characterization of macro- and microelements in both flours. In the refined flours, significant changes were observed in the Mo, K, and P contents (Ariete variety) and Ca, K, P, and S (Ceres variety) (Table 1). This oscillation of values can be justified by the industrial processes in the grain such as, in this case, dehulling and milling. During these processes, the micronutrient content decreases [16]. To increase palatability, thus improving the sensory properties, it is common to also use washing, soaking, and cooking techniques [17]. To sustain plant growth, P is remobilized/retranslocated and, as such, is considered highly mobile within plants [18]. In the Ariete variety, and after processing, the content remained detectable in the refined flour, suggesting greater mobility in this variety. However, studies pointed out that P is not very mobile in plants, which may justify the absence of values in the refined flour of the Ceres variety [19]. Rice crop contributes about 20% to global caloric consumption [20]. The ash content showed significant differences, with a tendency toward higher values in the Ariete variety (Figure 1). In the Ariete variety, there were significant alterations between brown and white grains, also justifiable by the application of industrial processes (Figure 2). In turn, in the Ceres variety, densities were statistically similar (Figure 2). It was observed that the brown grains of the Ariete and Ceres varieties were statistically similar, which may be useful for making whole-grain products with different varieties. Considered as one of the main technological quality parameters, the amylose content of the Ariete variety was 19%, while that of the Ceres variety was 22%, allowing the grains to be classified as having low and intermediate amylose content, respectively [6,21]. Low contents are beneficial as the grains are stickier, wetter, and softer [21]. In turn, studies have reported that higher amylose values are related to decreased glycemic response [22]. Studies have used the CIELab scale to quantify amylose in rice grains [23]. According to other studies, the amylose content in cooked rice affects the brightness (L) of the samples [6,21]. In both varieties, brown and white grains showed significant differences in the colorimetric parameters (L, a*, and b*) (Figure 3). The L parameter increased in the white rice grain, which is in accordance with studies wherein the same trend is seen when the endosperm and bran are removed [24]. Regarding the a* parameter, the brown grains showed a red color while the white grains showed a green color. The b* parameter corresponded to the yellow color, which is much more evident in brown grains. The decrease in a* and b* values is justifiable with the processing that the grains undergo, wherein pigments present in the outer layers of the grain are removed. Brown rice grains have bran (aleurone layer) that contributes to the different coloration compared to white grains [16]. In addition to the above, storage and drying processes should also be considered in this type of study. These external factors can influence the color of the grain [25]. Thus, the mineral contents, combined with the quality parameters, showed common characteristics required for high industrial and gastronomic potential.

5. Conclusions

This study, conducted in one of the regions that produce the most rice nationally (Ribatejo, Portugal) used rice (*Oryza sativa* L.) of the Carolino type, of Ariete and Ceres varieties, which are of Italian and Portuguese origin, respectively. After analyzing the macro- and microelements (Mo, Ca, K, P, and S) in the brown and refined flours it was concluded that there are significant differences; namely, the Mo content varied significantly between 4.7–11.2 mg·kg^{-1} in the whole flour of Ceres and Ariete, respectively, while P content was only detected in the flour of the Ariete variety. The ash content value in the refined flour of the Ariete variety showed a tendency toward higher values in the Ceres variety, implying significant differences. Quality parameters such as density varied between 1301–1651 kg/m^3 (in the Ariete variety) and 1492–1573 kg/m^3 (in the Ceres variety). Additionally, colorimetric indexes (L, a*, and b*) in brown and white grain showed significant differences. It was concluded that despite of the differences found in both varieties, the minerals contents, combined with the quality parameters, showed common characteristics required for high industrial and gastronomic potential.

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