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Chemical composition and color analysis of BRSMG Caravera rice in relation to urea sources and dosages

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Abstract

Rice is an essential food for the diet of the Brazilian population. Parboiling and nitrogen fertilization are processes which aim to improve the physical-chemical composition of these grains. The objective of this study was to evaluate the chemical composition as well as the color of unparboiled and parboiled rice fertilized with policote and kimcoat urea in dosages of 40, 80, and 120 ha^{-1}. According to the Tukey test at 5% probability, only the moisture contents are different between Factorial and Additional, that is, the moisture content is higher for the treatment without fertilizers. The application of Policote 120 kg ha-1 highlighted the protein content in parboiled and unparboiled rice. The application of urea coated with Kim Coat 120 kg ha-1 also highlighted the protein content, but only for unparboiled rice. Also, the parboiling process impacts other parameters of the chemical composition and color of the rice.

Keywords: Parboiled rice. Proximate composition. Nitrogen. Polymers. Coating

1. Introduction

Rice is an essential food for the diet of the Brazilian population, with more than 94% of people, within every social class, consuming it at least once a week. Among the most common forms of consumption, there can be found the polished white rice (70%) followed by parboiled rice

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(25%), and whole rice (3-5%) (Elias, Gularte, Schirmer, & Amato, 2005; Behrens, Heinemann, & Lanfer-Marquez, 2007).

There are many factors that might impact the technological and nutritional quality of rice. Among them, there are the phenotypic variation, the moisture conditions, the fertilizers, the soil qualities, the processing, and the storage, among others (Castro,Vieira, Rabelo, & Silva, 1999). Among the types of grain processing, the parboiling stands out for its multiple physical and nutritional benefits. However, there are very few researches devoted to the gathering of such data (Balbinoti, Nicolin, Matos Jorge, & Jorge, 2018). In the parboiling process, the hydrothermal treatment is applied to the rice grains in the husk, and performed in three steps: soaking, steaming, and drying. Due to these operations, minerals, vitamins, and other hydrosoluble compounds migrate alongside the water to the interior of the grain. The process also involves leaching which adds of the affirmations by Priyantono, Sulfianti, and Risman (2021) that there are changes in the chemical composition of rice. The starch gelatinization and retrogradation restructure the grains, increasing the retention of the nutrients mentioned. It reduces the breaks and losses in polishing, which increases the industrial yields, shelf life, and nutritional value of rice when compared to the conventional process of industrialization of the white rice (Amato & Elias, 2005; Behrens, Heinemann, & Lanfer-Marquez, 2007; Patindol, Newton, & Wang, 2008; ABIAP, 2010).

Nitrogen (N) is an essential macronutrient for plants since it is a structural component of amino acids and proteins. Also, it is part of chlorophyll molecules, of cytochromes, and of every enzyme and coenzyme. Nitrogen fertilization adds to the availability of N in the soil, but there is a big loss of the mineral for the environment. In order to minimize the losses of N in agriculture and increase productivity profitably, methods of slow and gradual release of nutrients were developed. They allow to decrease the losses that usually happen with the use of

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urea (Nyborg, Solberg, Malhi, & Izaurralde, 1995). These fertilizers are coated with polymers that delay the initial availability of nutrients through different mechanisms. The objective is to make them available for the crops for a larger period of time, and optimize the absorption by the plants, reducing losses. Two examples of polymers are the kimcoat and the policote which coat the urea and decrease the losses of nitrogen in the system soil-plant-atmosphere (Shoji, Delgado, Mosier, & Miura, 2001; Edmeades, 2004).

Therefore, this study aims at evaluating the chemical composition and the color of grains of unparboiled and parboiled rice fertilized with urea policote and kimcoat at different dosages.

2. Material and methods

2.1. Acquisition of raw materials

Rice samples were donated by EPAMIG (Empresa de Pesquisa Agropecuária de Minas Gerais). Part of the samples was destined to parboiling, and, later, to processing.

After processing, only whole normal grains unparboiled and parboiled were used in order to obtain the chemical composition and the color analysis.

2.2. Experimental design

For the experiment, unparboiled and parboiled rice were taken into account, being treated with dosages of 40, 80, and 120 kg ha^{-1} of urea coated with policote and kimcoat polymers, and going through a treatment with no nitrogen fertilization. Thus, this study went through a 3 factorial design (2 rice subgroups x 2 urea coatings x 3 dosages) + 2 additional treatments (unparboiled rice with no fertilization, and parboiled rice with no fertilization) in randomized blocks, performed in triplicate, in a total of 42 treatments.

2.3. Chemical composition

The proximate composition of rice grains was determined by the following analyzes of the dry

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matter:

- Moisture: according to the AOAC (2000) method n. 925.09, until achieving constant weight;
- Ether extract: according to the AOAC (2000) methodology n. 925.38;
- Crude protein: following AOAC's (2000) micro-Kjeldahl methods n. 920.87, applying the correction factor of 5.95;
- Ash: following AOAC's (2000) gravimetric method n. 923.03 with 550°C calcination, and keeping the sample in a FORTINEC muffle, model 1926, Brazil;
- Crude fiber: according to Van de Kamer and Van Ginkel's (1952) methodology;
- Sugar fraction (non-nitrogenized extract): method of difference, in accordance with AOAC (2000).

2.4. Color analysis

The color analysis of the rice samples was based on the methodology suggested by Gennadios, Weller, Hanna, and Froning (1996). The CIELab system was used through a Minolta colorimeter, model Chroma Meter CR 3000 (Japan) through D65 reflectance, in order to come up with a conclusion about the interference of treatment in the final color of the product. The color parameters measured were: L – luminosity (0 = black to 100 = white), a = between green (-60.0) and red (+60.0), and b = between blue (-60.0) and yellow (+60.0). The calculations to express the color differences were made through Equation 1.

$$\Delta E^{*}= [(\Delta L)^{2}+(\Delta a^{*})^{2}+(\Delta b^{*})2]^{0,5} \quad (1)$$

In which:

ΔE^{*} = value for color difference;

ΔL = difference between the white pattern and the sample reading;

Δa^{*} = difference between the white pattern and the sample reading;

Δb^{*} = difference between the white pattern and the sample reading.

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2.5. Statistical analysis

The analysis of variance was carried out for each variable. The level of significance was taken into consideration. All the necessary analyzes were performed with the R software (R Core Team, 2015).

To compare the chemical composition between factorial (addition of coated urea, regardless of treatment) and additional (without addition of urea), the Tukey mean test was performed at 5% probability using the Sisvar software (Ferreira, 2019).

3. Results and discussion

The urea dosages, 40, 80 and 120 kg ha^{-1}, are generally used in experiments with urea application in rice crops, which is why they were used in the present work (Ponte et al, 1981; Lopes et al., 2013).

3.1. Centesimal composition

In table 1, it is possible to observe the average values found for the factorial and additional of the chemical composition of rice grains from this work.

Table 1. Average values, in g 100g^{-1} (%), of variables moisture, ether extract, ash, crude fiber, crude protein, and non-nitrogenized extract for factorial and additional, in BRSMG Caravera rice.

Treatment	M	EE	A	CF	CP	C
Factorial	12.09±0.35^{a}	0.48±0,10^{a}	0.46±0.09^{a}	4.79±0.87^{a}	8.29±0.95^{a}	73.89±1.34^{a}
Additional	12.27±0.57^{b}	0.67±0.07^{a}	0.54±0,.10^{a}	5.29±0.84^{a}	7.53±1.39^{a}	73.71±2.86^{a}

M = Moiture; EE = Ether Extract; A= Ashes, CF = Crude Fiber; CP = Crude Protein e C = Carbohydrates/non-nitrogenized extract. Means followed by the same letter, in the column, do not differ from each other, using the Tukey test, at 5% probability.

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According to the Tukey test at 5% probability, only the moisture contents are different between Factorial and Additional, that is, the moisture content is higher for the treatment without fertilizers. Showing that the application of coated urea (Policote and Kimcoat) on rice grains does not change the chemical composition with the exception of moisture content.

An effect was noticed among the unparboiledd and parboiled rice subgroups, the urea coatings, and the fertilizer dosages. The rice subgroup was the most impactful in the results for moisture and crude fiber.

The moisture level was higher in parboiled rice, with an average of 12.32%. Meanwhile, in the unparboiled rice, the average was of 11.86%. This result is close to the one found by Naves (2007) who obtained values around 12g $100g^{-1}$ in unparboiled rice. Bortolini (2010) found values of 10.3 g $100g^{-1}$ in parboiled rice.

Regarding crude fiber, the parboiled rice also presented a higher average when compared to polished rice, around 5.53% to 4.05%, respectively. After polishing, rice loses bran connected to the grain and, consequently, a number of nutrients. What justifies the parboiled rice presenting higher percentage of crude fiber is the soaking step in which the nutrients, the fiber, and other compounds located in the external part of the grain migrate to its interior, increasing the nutritional value.

Results for the average concentration of ether extract and ash do not include significant interaction. Higher levels of ether extract were found in the polished rice than in the parboiled rice while the opposite happens with the ashes as in the work of Pal, Singh, Kaur, and Kaur (2018). The average ether extract values were 0.50 g $100g^{-1}$ in polished rice, and 0.47 g $100g^{-1}$ in parboiled rice. According to the work of Onmankhong, Jongyingcharoen, and Sirisomboon (2021), the higher the immersion time, the higher the ether extract level. Meanwhile, the same value decreases as the parboiling temperature increases.

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In accordance to Heinemann, Fagundes, Pinto, Penteado, and Lanfer-Marquez (2005) and Walter, Marchezan, and De Avila (2008), the concentration of the main components of rice, with the exception of starch, move from the periphery to the core of the grain duo do the removal of the bran. Increased polishing may remove almost all the lipids and ashes.

The average values found for ashes were 0.39% for the polished rice and 20.53% for the parboiled rice, lower to the ones found in the work of Pal, Singh, Kaur, and Kaur (2018). The highest mineral concentrations are found, mostly, in the external layers of the caryopsis. There are carried to the interior of the grain during soaking through diffusion and leaching. Thus, there are highest levels of ash in the parboiled rice. Priyantono, Sulfianti, & Risman (2021) obtained higher levels of minerals, that is, ash, in parboiled rice.

In relation to the protein level, there was a significant triple interaction among the rice subgroups, the urea coating, and the dosages, as seen in Fig. 1. It is possible to observe that the values found in the parboiled rice were higher than the values found in the unparboiled rice. These results are similar to the ones in the work of Pal, Singh, Kaur, and Kaur (2018) who found higher levels for parboiled rice (9.46 – 11.22 g $100g^{-1}$). Likewise, the rice fertilized with policote urea also presented higher values when compared to the rice fertilized with kimcoat urea. When it comes to the dosages used, it is possible to observe that, in the unparboiled rice, it was found a similar behavior for both the rice fertilized with policote urea and the rice fertilized with kimcoat urea. There were lower values when using the dosage of 80 kg ha^{-1} and higher values when using the dosage of 120 kg ha^{-1}. In the parboiled rice, the behavior was inverted with lower values for the 80 kg ha^{-1} dosage of policote urea and higher with same dosage of kimcoat urea.

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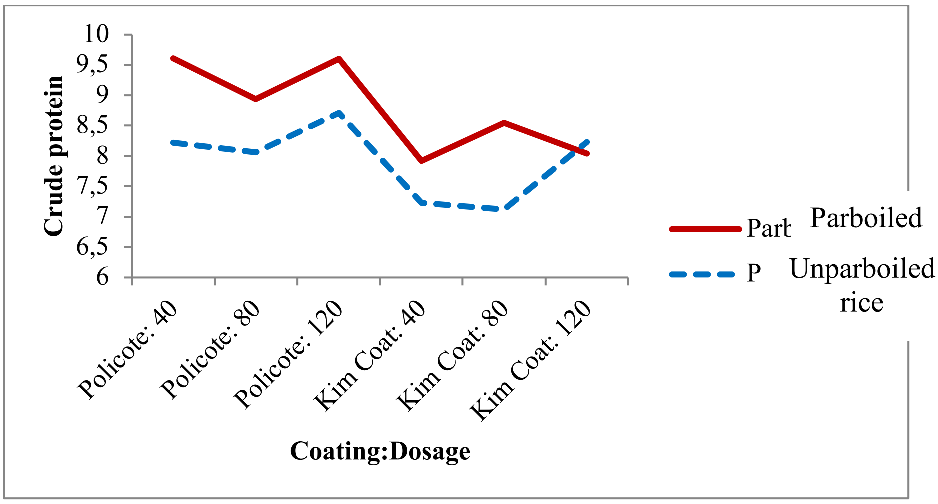

Figure 1. Unfolding of the interaction Subgroup-Coating-Dosage for the response variable protein

According to Amato, Carvalho, and Silveira Filho (2002), the higher protein levels are located, mostly, in the more external layers of the caryopsis. Meanwhile, the highest proportion of carbohydrates is found the more internal layers. However, there is a difficulty of protein migration to the interior of the grain due to size of molecules. Thus, there is difficulty in their solubilization. Therefore, the highest protein value in the parboiled rice can be a result of the parboiling process leading to a higher retention of peripheral fractions in the grain where this component is more concentrated. This leads to the removal of higher proportions alongside the bran during the processing of the white rice.

Around 1% of rice proteins are removed with the bran during polishing. This reduction corresponds to 10% of the protein total in the rice. Therefore, even when not in the stage of whole grain, rice still is an important protein source. The protein content in the grains changes a lot with genetic and environmental factor as well as crop handling. Its interaction with starch produces a complex structure that directly influences the mechanical properties of the grain, especially in relation to the resistance to polishing abrasiveness (Singh, Kalia, & Malhotra, 2000; Sujatha, Ahmad, & Bhat, 2003).

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The carbohydrate levels found in the unparboiled rice sample in this study were lowers than the ones found by other authors which were 78.8 g $100g^{-1}$ and 80.4 g $100g^{-1}$, for Castro, Vieira, Rabelo, and Silva (1999) and TACO (2015), respectively. In relation to the parboiled rice samples, it is possible to observe lower values than the ones found in the unparboiled rice. Castro, Vieira, Rabelo, and Silva (1999) presented higher values than the ones found in this study which were 81.3 g $100g^{-1}$. In Fig. 2, the interaction is proved. These results are in accordance to other studies that deal with the increase of nutritional value in parboiled rice grains (Rao, 1966 *apud* Lv, Li, Chen, Chen, & Zhu, 2009; Elbert, Tolaba, & Suárez, 2001; Bhattacharya, 2004 *apud* Lamberts, Rombouts, Brijs, Gebruers, & Delcour, 2008).

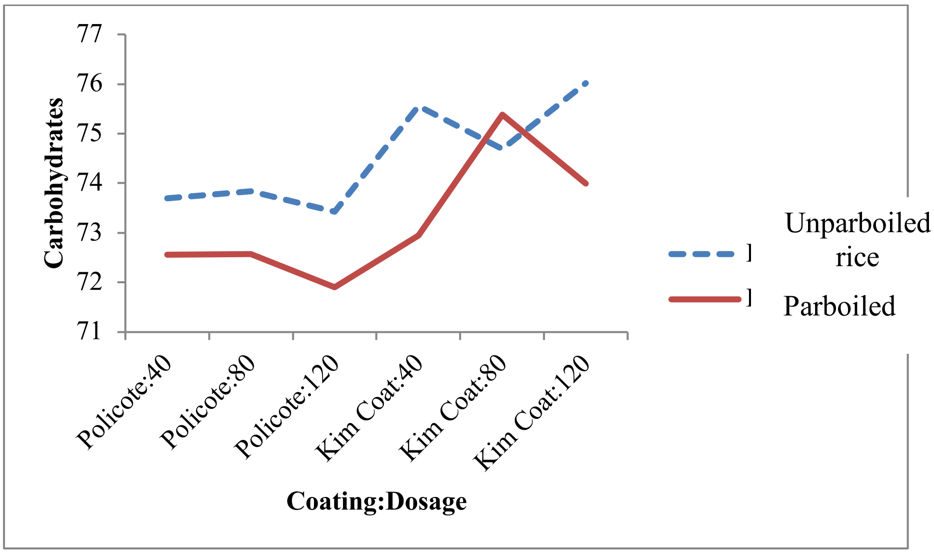

Figure 2. Unfolding of the interaction Subgroup-Coating-Dosage for the response variable carbohydrates

3.2. Color analysis

In Fig. 3, it is possible to observe the triple interaction in relation to the color of the rice studied.

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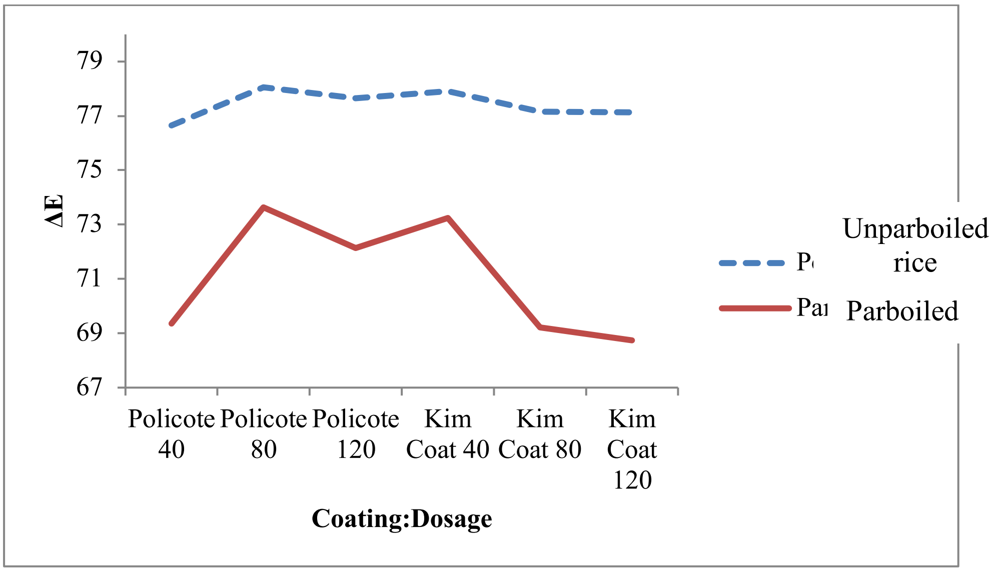

Figure 3. Unfolding of the interaction Subgroup-Coating-Dosage for the response variable ΔE.

It can be said that the fact that impacted the color the most was the rice subgroup (unparboiled and parboiled rice) in which the parboiled rice had lower values of ΔE than the polished rice. Parboiling intensifies the color of the grains, giving them a dark yellow or amber color. This might lead to devaluation of the product since most people prefer a lighter color for it (Amato & Elias, 2005). In the study of Pal, Singh, Kaur, and Kaur (2018), which evaluated the effects of parboiling in phenolic, protein, and paste properties of different rice varieties, it was proved that there is a decrease of whiteness in parboiled rice. The color change occurs during the parboiling process, and it is due to many factors such as soaking temperature and time, gelatinization soaking and time, and drying duration and methods (Pillaiyar & Mohandoss, 1981; Elbert, Tolaba, & Suárez, 2001). Other studies register that the color changes occurred in the grains during parboiling can be result of a migration of pigment from the hull to the grain, enzymatic darkening, or, yet, Maillard-type non-enzymatic darkening (Itani, Tamaki, Arai, & Horino, 2002; Lamberts et al., 2007). For Lii, Mauromoustakos, and Wang (2018), among parboiling conditions, evaporation temperature is the predominant factor to affect the color of

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the parboiled rice.

In relation to the coating polymers used, it was possible to observe that, in the polished rice, the values found for both policote and kimcoat, in the three dosages, were close and did not present significant differences. On the other hand, in the parboiled rice, when using policote urea, a lower value was obtained when fertilized with the 40 kg ha^{-1} dosage, and a higher value with the 80 kg ha^{-1} dosage. The opposite happened with the rice fertilized with kimcoat urea that obtained a higher value in the 40 kg ha^{-1} dosage and a lower value in the 120 kg ha^{-1} dosage.

4. Conclusions

The application of Policote 120 kg ha-1 highlighted the protein content in parboiled and unparboiled rice. The application of urea coated with Kim Coat 120 kg ha-1 also highlighted the protein content, but only for unparboiled rice. Also, the parboiling process impacts other parameters of the chemical composition and color of the rice.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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