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Contribuition for the physical characterization of carolino rice

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ABSTRACT

Most of the rice produced in Portugal is of the Carolino type, botanically classified as *Oryza sativa* ssp. Japonica. Nowadays, this rice is playing a vital role in Portuguese rice trading, and therefore the aim of this work was to evaluate some cultivars as to biometric characteristics, water uptake ratio, cooking time and textural properties.

Five types of Carolino rice were collected for analysis. Biometric characteristics (length, width, length/width ratio) were evaluated using an automatic biometric equipment. Other morphological characteristics were evaluated: white vitreous, total whiteness, vitreous percentage, percentage of chalky area and kett (using a colorimeter). Texture was evaluated on compression by texture profile analysis with a texturometer.

The samples studied showed biometric characteristics to be commercially classified as long grains type-A. The results indicated that one of the samples was quite different from the others, presenting less adhesiveness, and lower hardness, springiness and cohesiveness. Also some differences were found between different rice samples regarding colour characteristics, cooking time and water absorption.

KEYWORDS

Carolino rice;
Color;
Cooking time;
Morphology;
Water absorption;
Texture.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereals cultivated worldwide, constituting the basic food for a large number of human beings, sustaining two-thirds of the world population[1–3]. Rice is one a major cereal crop, which has an important role in human nutrition, being rich in fibre and antioxidants[4,5]. Rice starch is particularly important for determination of cooked rice quality and nutrition based on its physicochemical properties and digestibility[6,7].

Carolino rice is one of the most popular cultivars of rice widely consumed in Portugal, and it belongs to Japonica subspecie. Grain-type preferences vary among consumer groups. The marketing values of rice as an agricultural product depend on its physical qualities after harvesting. The percentage of whole grain is the most important parameter for the rice processing industry, related with a common demand of all rice consumers, that the grain, or head rice, must be well polished and unbroken. The polishing process aims to improve the physical properties as well as the sensory charectaristics of rice, and at the same time increasing its staibilty during storage[8–11].

The geometric structure and weight of rice kernels determine the physical characteristics and types of rice grains (shape, volume and density). Grain shape, considering the length and the ratio of kernel length to kernel width, is used by the rice industry in Portugal to classify rice into three types:short or round grain (length ≤ 5.2 mm and length/width ratio < 2.0), medium grain (length between 5.2 and 6 mm and length/width ratio < 3), and long grain rice existing in two groups, one with length > 6 mm and length/width ratio of 2–3, and other with length > 6 mm and length/width ratio < 3[12,13].

The economic value of rice depends on its cooking and processing quality, which can be measured in terms of water uptake ratio, grain elongation during cooking, solids in cooking water, cooking time[14] and texture properties. Furthermore, consumers' choice of rice varieties is largely based on grain and cooking qualities. Rice quality differs according to the variety and processing method used. The differences in quality, which are mainly attributed to differences in colloidal structure and the extent of swelling of any variety of rice on cooking have always been used as index of quality[14].

Within an individual rice particle, various processes occur during cooking. The heating, water uptake and swelling of the rice particle, all involve diffusive processes[15]. When water is present at sufficiently high temperatures, the starch undergoes a gelatinization transformation. Many rice studies have concentrated on the soaking of rice grains at fixed temperatures or the parboiling process. For temperatures below 50°C, the grains absorb a limited amount of water up to approximately 30% moisture content (wet basis). The resulting grains are not cooked because the starch has not undergone gelatinisation[16]. From common experience with small samples, it is known that soaking rice grains in water at 25°C for about one hour is required before cooking at temperatures above 70°C for 20 minutes or more. As water is taken up by a rice particle, the starch granules undergo a gelatinization process, the term generally used to describe the swelling and hydration of the granular starch[17].

The objective of this work was, therefore, to evaluate five commercial Carolino rice cultivars traded and consumed in Portugal, in relation to biometric characteristics, water uptake ratio, cooking time and texture properties.

MATERIALS & METHODS

Sampling

Five types of Carolino rice were collected from the Portuguese trade market, and they were coded with a number (the cultivar list was not revealed due to confidentiality). Flours were produced for texture measurements using a SK 100 Cross Beater Retsch hammer mill with a 1 mm sieve. After, they were sieved through a 0.5 mm sieve.

Biometric characteristics

Biometric characteristics of all rice grains were evaluated, using an automatic S21 (LKL, Brazil) biometric equipment and a C-300 (Kett, USA) colorimeter. The evaluated characteristics were length, width, and length/ width ratio. Other morphological characteristics were evaluated: white vitreous, total whiteness, vitreous percentage, percentage of chalky area and kett. These determinations were done using an automatic S21 (LKL, Brazil) biometric equipment and a C-300 (Kett, USA) colorimeter. An average of 700 grains for each cultivar were analysed regarding these characteristics.

Cooking time

This was determined according to Oko et al.[14] methodology with some modifications. 50 g of whole rice kernels from each sample were boiled in 500 ml distilled water. After 10 minutes 20 kernels were removed at one minute intervals until cooking. The cooking time was finish when cooked rice was pressed between two glass plates until no white core was left. This procedure was done three times for each sample.

Water absorption ratio

This was determined also following the procedure described by Oko et al.[14] with some modifications. 100.0 g of whole rice kernels from each Carolino rice sample were cooked in a 1000 ml distilled boiling water bath. The cooking time for each sample was in accordance with the cooking time already determined. After cooking, the samples were drained by removing the superficial water from the cooked rice. The cooked samples were then weighed accurately and the water uptake ratio was calculated as the ratio of final cooked weight to uncooked weight.

It was also measured the water absorption ratio after 13 minutes boiling for all the aromatic rice samples.

These procedures were done three times for each sample.

Texture properties

The texture profile analysis (TPA) for aromatic rice gels was made by a texturometer (TA.XT.Plus from Stable Micro Systems). The rice samples were prepared according to CEE Regulation n.º 2580[18], and a cake with 4 cm high and 5 cm diameter was shaped inside a specific mold made purposely for this experiment. The texture profile analysis was carried out by a two cycle compression test done with a flat P/75 probe and a load cell of 30 kg. The pre-test, test and post-test speed was 1 mm/s and the distance was 2 mm. TPAs were performed in 10 rice cakes for each sample and the textural properties measured werhardness, adhesiveness, resilience, cohesiveness, springiness and chewiness.

The extrusion force was also determined according to ISO 11747:2012[19]. The extrusion force test was done with a rice extrusion rig (probe HDP/RE) and a load cell of 50 kg. For this the cooked rice was introduced into the extrusion rig for analysis. The test mode was compression and the settings were 1.6 mm/s for test speed and 52 mm for distance. Also in this case 10 replications were made.

Statistical analysis

The results are presented as mean value and corresponding standard deviation for each case. Pearson correlation coefficients (r) for the relationships between properties were calculated. Results were analysed using the SPSS® for Windows version 21.0 software.

RESULTS & DISCUSSION

The length of the analysed samples of Carolino rice varied between 6.05 mm for sample C5 and 6.60 mm for sample C3, and the width varied from 2.27 mm in sample C4 to 2.59 mm in sample C3 (Figure 1). Therefore, the sample C3 was the one with bigger grains, for showing higher values in both dimensions. However, sample C4 was that with the biggest ratio length/width (2.82). Still, all the samples analysed are commercially classified as long grains type-A, because they present a length higher than 6 mm and the ratio length/width lower than 3 mm, but higher than 2 mm (Figure 1). The length and the ratio length/width presented an inverse association, with a correlation coefficient of r = - 0.87 (correlation significant at the 0.05 level).

The C5 sample presented the highest total whiteness (190) and vitrea whiteness (131) among the samples analysed, but a low plastered area (16%) (Figure 2). The Carolino rices showed a great discrepancy in the plastered area results, varying from 13% and 40%, for samples C1 and C2 respectively. There was a perfect negative relation between the percentage of vitrea area and the percentage of plastered area (r = -1.00) (correlation significant at the 0.01 level). The correlation analysis also revealed a strong correlation between the total and vitrea whiteness (r^2=0.74), and it was observed some variability in the color measurements. For all the samples the kett parameter (whiteness of all grain) showed high values, between 36 and 46, respectively

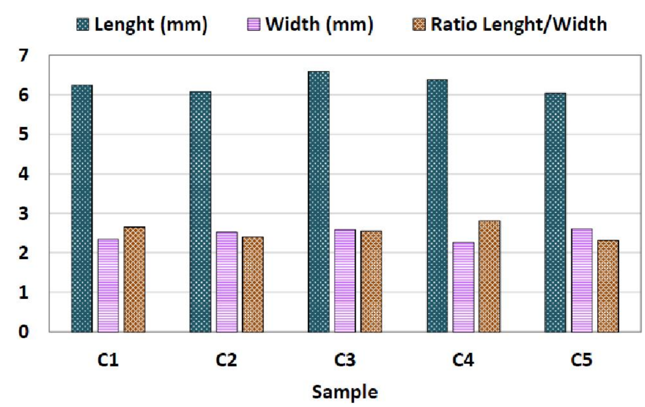

Figure 1 : Length, width and length/width ratio of Carolino rice samples

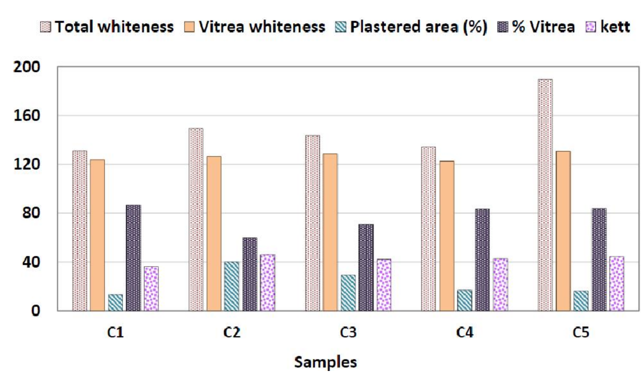

Figure 2 : Whiteness, vítrea, plastered area and kett of Carolino rice samples

for samples C1 and C2. Kett showed a moderate correlation with cooking time (r = 0.66). The degree of milling or polishing (e.g. polishing time and polishing pressure) is an important factor that influences the quality of milled rice. Excessive polishing often leads to a high degree of breakage and also the nutritive value is reduced considerably comprising a significant loss of natural fibre[20]. In contrast, a low degree of milling can yield a low-quality head rice which will reduce its market value as a result of the incomplete removal of the aleurone layers from the kernel[15]. The milling operation will influence morphological characteristics as white vitreous, total whiteness, vitreous percentage chalky area, and kett (reflective index). These characteristics could be changed after cooking, as it is the case of chalkiness. The chalkiness is an important physical property as it can determine whether a particular rice sample attracts a competitive price on the market, mainly because it cannot be seen after cooking[21–24].

The rice cooking quality characteristics evaluated included optimum cooking time and water absorption ratio. Among all the rice samples, the C4 had the lowest cooking time (Figure 3). The cooking time varied from 17 min (sample C4) to 22 minutes (sample C2), with a water uptake between 143.9 g (sample C1) and 182.5 g (C4) after achieving the cooking point. To compare the differences between the samples, the cooking time was also determined after 13 minutes of cooking, and the results showed that the water absorption varied from 101.9 g to 139.6 g, for samples C3 and C4, respectively. The variation in the cooking time could be traced to its gelatinization temperature since gelatinization temperature positively determines the cooking time of rice. It has been asserted that the higher the value of gelatinization temperature, the longer time it takes to cook the rice. Cooking time is primarily related to the surface area of the milled rice and unrelated to other grain properties[17,25]. In fact our results showed just a significant correlation between the cooking time and the L/W ratio (r = -0.74).

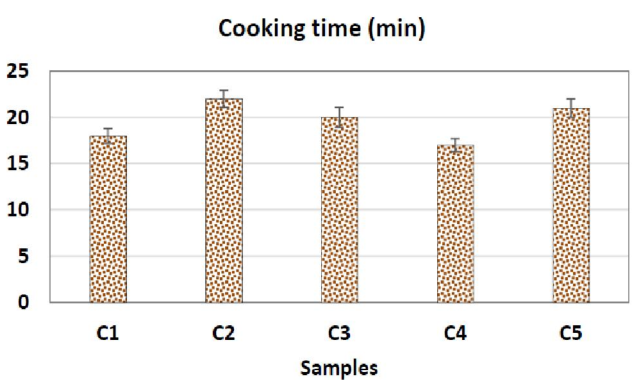

Figure 3 : Cooking time of Carolino rice saples

Water uptake is considered an important economic attribute of rice as it gives an indirect measure of volume increase upon cooking[26,27]. The water absorption ratio was determined at the cooking time for each sample and to all samples after 13 minutes of cooking, in order to evaluate all the samples at the same conditions (same cooking time) and when they were completely cooked. For the same cooking time, all the Carolino cultivars presented similar water uptake values (Figure 4). In spite of this, the sample C4 presented the highest water absorption ratio (2.83 and 2.40, respectively for cooking time and after 13 minutes), meaning that it cooked quickly and with high water uptake. One of the possible explanations to those differences could be attributed to amylose content. Amylose content might be responsible for high water uptake ratio, since rice with high amylose content tends to absorb more water upon cooking[14,27].

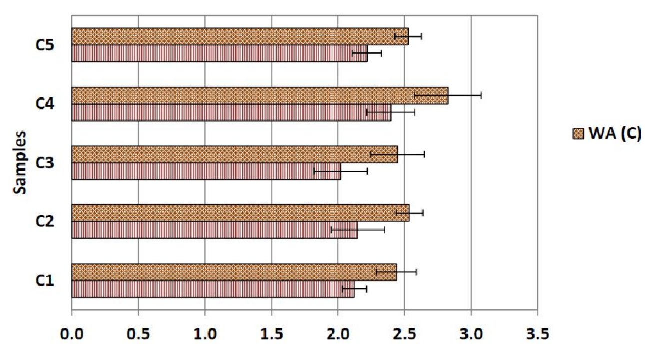

Figure 4 : Water absorption at the cooking time (WA (C)) and after 13 minutes (WA (13 min)) of Carolino rice samples

Figure 5 shows the hardness and chewiness for the rice samples analysed by means of TPA test. Hardness corresponds to the force required to deform the product to a given distance, representing the force to compress between molars, bite through with incisors or compress between tongue and palate. The chewiness is the number of chews (at 1 chew/sec) needed to masticate the sample to a consistency suitable for swallowing[28,29]. The hardness varied between 2.01 N and 3.54 N, for samples C4 and C3, respectively, and chewiness varied in the range 0.79-1.84 N for the same samples. This results is expected, since these two textural parameters

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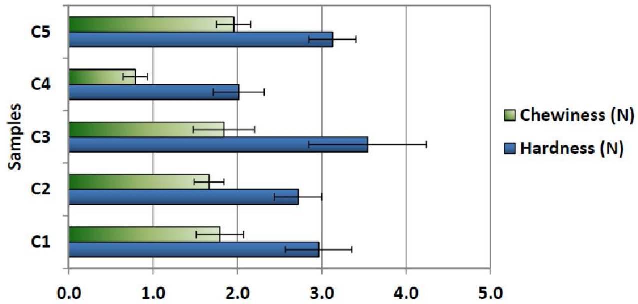

Figure 5 : Hardness and chewiness of Carolino rice samples

are intrinsically related, also as demonstrated by the strong correlation found between the hardness and the chewiness (r = 0.92) (correlation significant at the 0.05 level).

The textural properties resilience, springiness and cohesiveness are represented in Figure 6.

Cohesiveness represents the internal forces in the food, which maintain the sample cohesive and corresponds to the degree to which the sample deforms before rupturing when biting with the molars. Springiness is how well a product physically springs back to the original shape after being deformed by partial compression. Resilience is the strain energy per unit volume to a limit of proportionality, i.e. the energy used when applying a force to a material without occurring rupture, with or without any residual strain[28,29]. The values of resilience varied from 20.84% (sample C1) to 32.41% (sample C5), while the values of springiness varied between 65.47% (sample C4) and 85.91% (sample C2), and the values of cohesiveness varied in the range 58.70-77.8% for samples C4 and C5, respectively. In general the samples showed a high springiness and cohesiveness, with sample C4 presenting the lowest values. Cohesiveness was found strongly correlated with other variables, namely the ratio length/ width (r = -0.94, correlation significant at the 0.01 level),

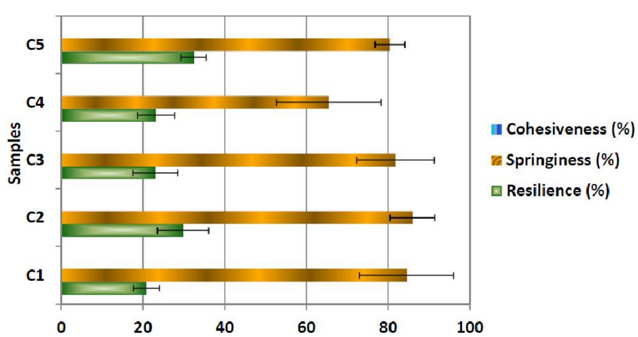

Figure 6 : Cohesiveness, springiness and resilience of Carolino rice samples

cooking time (r = 0.71), hardness (r = 0.66), resilience (r = 0.74), springiness (r = 0.74) and chewiness (0.85). In this way, cohesiveness tends to be higher for rice grains which are more spherical and it increases with increasing cooking time.

Figure 7 shows the values of adhesiveness for the rice samples analysed. Adhesiveness is related to the force required to remove the material that adheres to a specific surface, such as lips, palate or teeth[28]. The Carolino rice when cooked is expected to be sticky, and therefore it is not surprising the high values for adhesiveness registered, varying between 4.58 N.s and 8.45 N.s (absolute values), for most of the samples, with just one exception, sample C4, which showed a very low absolute value of adhesiveness (1.47). Adhesiveness was found strongly negatively correlated with vitrea whiteness (r = -0.94, correlation significant at the 0.01 level), with cooking time (r = - 0.75) and cohesiveness (r = -0.74). This signifies that with increasing cooking time and for more cohesive samples, the adhesiveness is more negative, and therefore more adhesive.

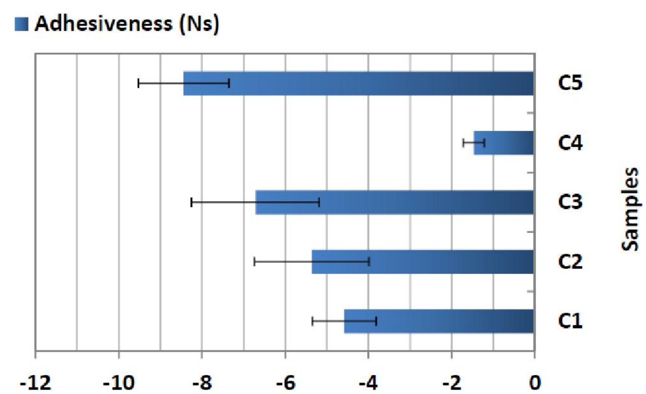

Figure 7 : Adhesiveness of Carolino rice samples

The extrusion force measures the kernel resistance to extrusion after cooking[19], and is presented in Figure 8 for the samples at study. The lowest value was registered for sample C1 (0.34 kg/m^2) and the highest for sample C3 (0.45 kg/m^2). The sample C3 showed the highest value for extrusion force and also for hardness in the TPA compression test. The extrusion force was found strongly correlated with rice kernel length (r = 0.80).

The textural properties of cooked rice are greatly influenced by the ratio between amylose and amylopectin, as well as by the pattern of α-amylolysis[30].

Also the degree of milling was found to have influence on the texture of rice[31]. Soaking is an essential process to diffuse water inside rice grain and it improves the palatability of cooked rice, however, the conditions for this process may influence cooked rice texture[32].

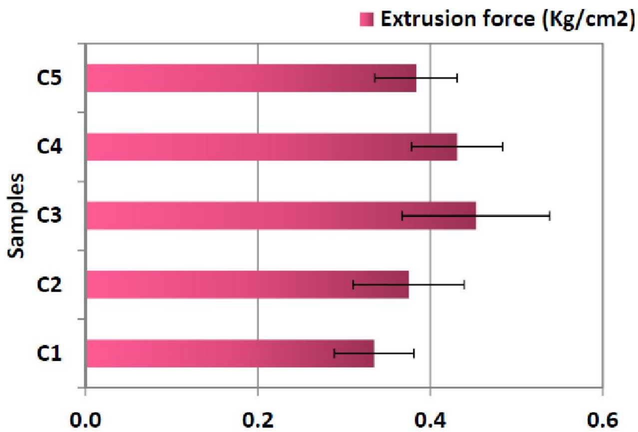

Figure 8 : Extrusion force of Carolino rice samples

CONCLUSIONS

Generally it could be concluded that the Carolino rices evaluated are classified as long type-A rice, which is a good characteristic to the Portuguese trade, because long kernel rices are market leaders due to consumers wishes and needs. Furthermore, they presented high values of whiteness, which is also valued commercially. The Carolino rice samples evaluated showed differences considering the colour characteristics, mainly in the total whiteness, plastered area and % vitrea. The sample C2 exhibited weak physical characteristics, especially milling recoveries, due to the high incidence of chalkiness or plastered area.

Generally, the textural properties of the Carolino rice cultivars tested were similar, but the C4 cultivar presented some distinguished characteristics, being less hard, less cohesive, less elastic and less adhesive. Finally, the C4 sample cooked in less time and absorbed a higher quantity of water when it was cooked.

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