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Scientific Article

Chemical and mineral composition of the raw and cooked immature grains of cowpea genotypes

Composição química e mineral dos grãos crus e cozidos de genótipos de feijão-caupi

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ABSTRACT - Immature cowpea grains are a rich source of proteins, minerals, dietary fiber, and phenolic compounds and also have a high antioxidant capacity compared to dry grains. Its consumption promotes a healthy and diversified diet. The objective of this work was to evaluate the cooking time and chemical and mineral composition of the raw and cooked immature grains of different cowpea genotypes. Four genotypes, two elite lines (MNC00-595F-27 and MNC05-847B-123) and two commercial cultivars (BRS-Tumucumaque and Vagem Roxa-THE) were analyzed. Cooking time was evaluated using the Mattson cooker. Proximate composition and minerals were determined. A completely randomized design with three replications in factorial scheme 1 (genotype) × 2 (raw and cooked grains) was adopted, except for cooking quality. The genotypes MNC05-847B-123 and BRS-Tumucumaque differed from the other genotypes, presenting faster cooking of the immature grain. Cooking increased the moisture content and reduced ash, lipid, protein, and carbohydrates contents and total energy value. The lines MNC05-847B-123 and MNC00-595F-27 showed higher contents of the nutrients of the centesimal composition after cooking than the local cultivar Vagem Roxa-THE, except for the moisture content. The mineral content decreased after cooking, with Fe, Zn, and Mn contents having the least losses with thermal processing. The lines MNC05-847B-123 and MNC00-595F-27, even with losses after the thermal processing of the immature grain, have nutritional potential as cultivars for the green-bean market.

Keywords: *Vigna unguiculata*. Green bean. Proximate composition. Minerals. Thermal processing.

RESUMO - Os grãos imaturos de feijão-caupi são uma rica fonte de proteínas, minerais, fibra alimentar e compostos fenólicos e também possuem alta capacidade antioxidante em comparação aos grãos secos. O seu consumo promove uma alimentação saudável e diversificada. O objetivo deste trabalho foi avaliar o tempo de cozimento e a composição química e mineral de grãos imaturos crus e cozidos de diferentes genótipos de feijão-caupi. Foram analisados quatro genótipos, duas linhagens elite (MNC00-595F-27 e MNC05-847B-123) e duas cultivares comerciais (BRS-Tumucumaque e Vagem Roxa-THE). O tempo de cozimento foi avaliado utilizando-se o cozedor de Mattson. Foram determinados a composição centesimal e minerais. Adotou-se o delineamento inteiramente casualizado com três repetições em esquema fatorial 1 (genótipo) × 2 (grãos crus e cozidos), exceto para qualidade de cozimento. Os genótipos MNC05-847B-123 e BRS-Tumucumaque diferiram dos demais genótipos, apresentando cozimento mais rápido do grão imaturo. O cozimento aumentou o teor de umidade e reduziu o teor de cinzas, lipídios, proteínas e carboidratos e o valor energético total. As linhagens MNC05-847B-123 e MNC00-595F-27 apresentaram teores de nutrientes da composição centesimal mais altos após o cozimento que a cultivar local Vagem Roxa-THE, exceto para o teor de umidade. O teor de minerais diminuiu após o cozimento, sendo que os teores de Fe, Zn e Mn tiveram as menores perdas com o processamento térmico. As linhagens MNC05-847B-123 e MNC00-595F-27, mesmo com perdas após o processamento térmico do grão imaturo, apresentam potencial nutricional como cultivares para o mercado de feijão verde.

Palavras-chave: *Vigna unguiculata*. Feijão-verde. Composição centesimal. Minerais. Processamento térmico.

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INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) or chorda bean, which has an African origin, is considered an important component in the diet of populations in developing countries in Africa, Latin America, and Asia. In regions prone to malnutrition in sub-Saharan African countries, cowpea has become a strategic leguminous crop in combating food insecurity and malnutrition (MEKONNEN et al., 2022). It is a crop of great socioeconomic importance in the Northeast region of Brazil, as it generates employment and income. Its grain is an excellent source of proteins, minerals, vitamins, and dietary fiber, contributing to the food security of thousands of people (MARTINS et al., 2023).

The global cowpea area, production, and yield in 2021 were 16.2 million ha, 9.6 million tons, and 603 kg ha^{-1}, respectively. The largest world producers are Niger, Nigeria, Burkina Faso, and Brazil (FAOSTAT, 2022; CONAB, 2022). In Brazil, in the 2021/2022 agricultural year, cowpea occupied an area of 1.3 million ha, with a production of 623.800 tons and a yield of 462 kg ha^{-1}. The largest national producers are the states of Bahia (113,500 tons), Ceará (103,500 tons), Tocantins (96,700 tons), Piauí (83,500 tons), and Mato Grosso (75,700 tons) (CONAB, 2022).

Cowpea is a very versatile crop in terms of cultivation, marketing, and consumption. Three market segments for cowpea stand out in Brazil: dry beans, green-bean (pods to obtain the immature grain or the immature grain already threshed), and seeds. In addition to these markets, there are also those for snap bean (Yard-long bean) and processed bean (SOUSA et al., 2015; FREIRE FILHO et al., 2017; SOUSA et al., 2019).

The pods and immature grains of cowpea are a rich source of proteins, minerals and phenolics, also showing a high antioxidant capacity relative to dry grains of the species and other legumes. Its consumption promotes a healthy and varied diet (CARVALHO et al., 2022). Furthermore, the production of immature pods and grains requires a shorter cultivation period than that of dry grains, allowing the crop to escape from various abiotic stresses (drought and high temperatures) imposed by climate change (NTATSI et al., 2018).

The green-bean market is growing every day in Brazil, mainly in the Northeast region of Brazil, where immature beans are traditionally consumed in practically all states in the Northeast region of the country (SOUSA et al., 2019). The beans are highly appreciated in this region and are used as the main component of several typical dishes, especially “baião-de-dois”, a tasty combination of rice and bean (SILVA et al., 2013; VIEIRA; BEZERRA; SANTOS, 2021). The processing of frozen or canned immature grains is very promising and represents an alternative to the commercialization of cowpea in Brazil (ROCHA et al., 2012).

Cooking time is a key factor in choosing a cultivar by consumers who aim to save time in meal preparation. Prolonged cooking time should be avoided, as it can cause structural changes at the cellular level, reducing the availability of nutrients (MOTA et al., 2016; SILVA et al., 2016).

Studies on the chemical composition and mineral content of the immature cowpea grain have not been studied enough. The results have shown genetic variability for protein (9.65-13.25 g 100 g^{-1}), lipids (1.30-2.23 g 100 g^{-1}), carbohydrates (21.54-29.69 g 100 g^{-1}), total energy value (TEV; 102.07-170.91 kcal 100 g^{-1}), P (4.25-5.40 g kg^{-1}), Ca (0.60-1.00 g kg^{-1}), K (9.70-11.56 g kg^{-1}), Mg (1.60-2.00 g kg^{-1}), S (0.59-0.74 g kg^{-1}), B (9 .76-13 mg kg^{-1}), Fe (5.38-6.370 mg 100^{-1}), Zn (4.28-4.73 mg 100 g^{-1}), Mn (1.22-1.52 mg 100 g^{-1}), and Cu (0.6-0.99 mg 1,200 g^{-1}) (MELO et al., 2017; ARAÚJO et al., 2021; CARVALHO et al., 2022).

Thermal processing, henceforth referred to as cooking, is a fundamental preparation step for beans for consumption that is aimed at achieving palatability coupled with increased digestibility of nutrients, reduction/elimination of antinutrients and improved sensorial attributes such as aroma, taste, and texture (WAINAINA et al., 2021). Studies on the impact of cooking on nutrient contents in immature cowpea grain are scarce. The moisture content increased and protein, lipid, carbohydrate, and mineral contents and TEV decreased after cooking; however, in some cases, protein and lipid contents increased, depending on the genotype (COSTA, 2014; MELO et al., 2017).

Additional studies evaluating different cowpea genotypes are needed to obtain more concrete results on the nutritional and cooking quality of immature cowpea grains and the impact of cooking on the contents of these nutrients. The objective of this work was to evaluate the cooking time and chemical and mineral composition of raw and cooked immature grains of different cowpea genotypes.

MATERIAL AND METHODS

Experimental protocol

Samples of immature grains of cowpea genotypes were collected from a cultivation carried out under the same environmental conditions in the experimental field of Embrapa Meio-Norte, in Teresina-PI, in the year 2021. After harvesting, the samples were transported to the Bromatology laboratory of Embrapa Meio-Norte for preparation and analysis. The genotypes were represented by two elite lines of the commercial color class, green subclass (MNC00-595F-27 and MNC05-847B-123), selected for their good agronomic attributes (SOUSA et al., 2019), and two commercial cultivars of the white class, plain white subclass (BRS-Tumucumaque and Vagem Roxa-THE). The local cultivar Vagem Roxa-THE was used as a commercial standard for the green-bean market. The grains were hand selected to remove dirt and those of substandard quality. All analyzes on raw and cooked beans were performed in triplicate.

Samples of raw immature grains from cowpea genotypes were washed with distilled water, one part was subjected to the cooking test and another was weighed to determine the initial moisture and the remainder were placed in an oven at 60°C for 48 h. The grains were then ground in a zirconia ball mill, Retsch brand, model MM200, to obtain a flour to be used for the analyses. The flour was placed in a polyethylene bag and kept at a refrigerated temperature (4 ºC) until the analysis.

Cooking of immature grains

The cooking time was determined using the Mattson cooker, according to a previously described method by Mattson (1946), timed in minutes and evaluated in triplicate. A sample of 25 grains of each genotype was used. The timer was started only when the Mattson cooker was fully immersed in the beaker, with boiling water (100 °C). The cooking time was noted when the 13^{th} rod of a total of 25 completely pierced the grain.

Cowpea immature grains were cooked in a bean:water ratio of 1:3 (w/v), during the predetermined cooking time for each genotype. Subsequently, the grains were separated from the cooking broth, with the aid of a plastic sieve, and the cooked beans were homogenized in a mortar with a pestle, according to the method described by Pinheiro (2013), with some adaptations, since in this study the cooking broth was not homogenized together with the cowpea. All cooked samples were placed in polyethylene bags and stored under freezing until the time of analysis.

Proximate composition

Moisture determination was performed using the drying method in an oven at a temperature of 105 ºC (AOAC, 2019). The ash was determined using the muffle incineration technique at a temperature of 550 ºC (AOAC, 2019). The proteins were analyzed using the Kjeldahl method (AOAC, 2019). Lipids were analyzed using the Soxhlet method (AOAC, 2019). Carbohydrates were determined by difference from the other constituents of the centesimal composition.

The TEV was calculated according to Watt and Merrill (1963), using Atwater conversion factors (carbohydrates = 4.0, lipids = 9.0, proteins = 4.0).

Mineral composition

Mineral contents were analyzed using the atomic absorption spectrometry technique (AOAC, 2019). For the analyses of macro minerals such as Ca and K After the digestion step, the extracts of the minerals Ca, P, K, and Mg were swelled with distilled water to 20 mL. Then, 200 µL of each extract was used and transferred to a test tube; to this tube, 3.5 mL of strontium chloride and 3.3 mL of distilled water were added, and the mixture was homogenized. The solution was then read using a flame atomic absorption spectrophotometer, GBC brand, model B462, for the specific wavelength of the element to be analyzed using the equipment software. Ca, K, P, and Mg contents were obtained in parts per million (ppm) and then transformed to mg 100 g^{-1}.

The analyses of the microminerals Fe, Zn, and Mn were carried out using 200 mg of the sample, which were weighed and transferred to a digestion tube, with the addition of 5 mL of the digesting solution (nitro:perchloric solution, 2:1). The tubes were then placed in the digester block for approximately 2 h until reaching 200 °C. After digestion, the extracts were transparent and clear, with an approximate volume of 2 mL. Post digestion, the volumes of the extracts of minerals Fe, Zn, and Mn were increased to 20 mL with distilled water, homogenized, and then read in a flame atomic absorption spectrophotometer, GBC brand, model B462, previously selecting the specific wavelength of each element to be analyzed using the equipment software. Fe, Zn, and Mn contents were obtained in ppm and then transformed to mg 100 g^{-1}.

The experimental design used was completely randomized blocks, with three replications, in a factorial scheme 1 (genotypes) × 2 (raw grain, cooked grain) for all characteristics analyzed, except cooking quality, where only genotype was considered as a source of variation.

Statistical analyses

Based on the data obtained in the study, analyses of variance were performed and the means between genotypes were compared using the Tukey's test ($p < 0.05$) and, between the raw and cooked forms of each genotype, using the t-test ($p < 0.05$). Statistical analyses were performed using the SAS (SAS INSTITUTE, 2012) and Genes (CRUZ, 2016) computational programs.

RESULTS AND DISCUSSION

Cooking time

The mean cooking time of immature grains of four cowpea genotypes is presented in Table 1.

Table 1. Average cooking time of immature grains of four cowpea genotypes.

Genotype	Cooking time (min)
MNC05-847B-123	8.81 ± 0.64 c
MNC00-595F-27	14.17 ± 0.29 a
BRS-Tumucumaque	9.80 ± 0.55b c
Vagem Roxa-THE	10.87 ± 0.38 b

Mean of three replications + standard deviation. Means followed by the same letter in the column do not differ as analyzed using the Tukey's test ($p < 0.05$).

The genotypes showed significant differences ($p < 0.05$) among themselves in terms of cooking time. The line MNC00-595F-27 showed the longest cooking time (14.17 min). The cultivar Vagem Roxa THE showed intermediate cooking time (10.87 min). The line MNC05-847B-123 and the cultivar BRS-Tumucumaque showed the shortest cooking times of 8.81 and 9.80 min, respectively. According to Bezerra et al. (2019), a cooking time between 8 and 10 min is considered fast cooking and, therefore, adequate to meet current consumer demand.

The development of cultivars with rapid cooking is one of the objectives of Embrapa's cowpea breeding program. The immature grains of the genotypes evaluated in this study presented faster cooking than the dry grains of the commercial cowpea cultivars, which present an average cooking time of 18 min. (ROCHA; SILVA; MENEZES JUNIOR, 2017).

The line MNC05-847B-123 and the cultivar BRS-Tumucumaque had a shorter cooking time than that obtained by Aquino, Santos and Silva (2021), who observed an average cooking time of 12.6 min, on evaluating the immature grains of 30 cowpea genotypes.

Cooking time is of fundamental importance for the acceptance of a cowpea cultivar by consumers, as the time available for preparing meals is often limited. Thus, cultivars that present fast-cooking grains save time and energy (firewood/gas) in preparation. In addition, cultivars with a longer cooking time can lead to nutritional losses in the grain.

Proximate composition of raw and cooked immature grains

The results of the centesimal composition and the TEV of the raw and cooked immature grains of the evaluated cowpea genotypes are shown in Table 2.

Table 2. Proximate composition and total energy value (TEV) of raw and cooked immature grains of four cowpea genotypes.

Characteristic	Genotype	Raw grain (wet base)	Cooked grain (wet base)
Moisture (g 100 g^{-1})	MNC05-847B-123	66.27 ± 0.30 bA	66.26 ± 0.72 bA
	MNC00-595F-27	69.11 ± 0.14 aA	68.83 ± 0.40 aA
	BRS-Tumucumaque	67.67 ± 0.67 bA	66.19 ± 0.44 bA
	Vagem Roxa-THE	68.80 ± 0.20 bA	68.81 ± 0.86 aA
Ashes (g 100 g^{-1})	MNC05-847B-123	1.12 ± 0.11 aA	0.83 ± 0.08 aB
	MNC00-595F-27	1.14 ± 0.04 aA	0.64 ± 0.09 aB
	BRS-Tumucumaque	0.94 ± 0.03 bA	0.78 ± 0.09 aB
	Vagem Roxa-THE	1.01 ± 0.05 bA	0.54 ± 0.38 aB
Lipids (g 100 g^{-1})	MNC05-847B-123	0.45 ± 0.16 cA	0.11 ± 0.01 bB
	MNC00-595F-27	0.93 ± 0.13 aA	0.14 ± 0.02 bB
	BRS-Tumucumaque	0.54 ± 0.12 bA	0.27 ± 0.16 aB
	Vagem Roxa-THE	0.44 ± 0.03 cA	0.11 ± 0.01 bB
Proteins (g 100 g^{-1})	MNC05-847B-123	9.12 ± 0.14 aA	9.46 ± 0.78 aA
	MNC00-595F-27	8.98 ± 0.33 aA	9.26 ± 0.26 aA
	BRS-Tumucumaque	8.33 ± 0.22 bB	10.12 ± 0.70 aA
	Vagem Roxa-THE	8.13 ± 0.16 bA	8.90 ± 0.12 aA
Carbohydrates (g 100 g^{-1})	MNC05-847B-123	23.04 ± 0.27 aA	23.34 ± 1.17 aA
	MNC00-595F-27	19.84 ± 0.33 bB	21.13 ± 0.19 aA
	BRS-Tumucumaque	22.52 ± 0.24 aA	22.64 ± 0.93 aA
	Vagem Roxa-THE	21.62 ± 0.12 cA	21.64 ± 0.62 aA
TEV (Kcal 100 g^{-1})	MNC05-847B-123	132.73 ± 1.72 aB	137.19 ± 3.23 aA
	MNC00-595F-27	123.69 ± 0.63 cA	122.73 ± 1.40 bA
	BRS-Tumucumaque	128.25 ± 0.59 bB	133.49 ± 1.68 aA
	Vagem Roxa- THE	126.96 ± 0.84 bA	119.18 ± 2.03 bB

Mean of three replications + standard deviation. Means followed by the same lowercase letter in the row and uppercase in the column do not differ significantly as analyzed using the Student's t-test and Tukey's test ($p < 0.05$), respectively.

The moisture content in the raw immature grain ranged from 66.00 to 69.11 g 100 g^{-1}, with the moisture content in line MNC00-595F-27 differing significantly ($p < 0.05$) from that in the other genotypes. The moisture contents found in this study are higher than those obtained by Melo et al. (2017), who observed a variation of 58%-60% of moisture on evaluating the raw immature grains of four cowpea cultivars. The water content of a food is closely related to its stability, chemical composition, microbiological deterioration, and its general quality (SILVA; TASSI; PASCOAL, 2016). Thus, these characteristics will be affected differently, considering that the moisture content in immature grains varied between the genotypes evaluated. The moisture content of cooked immature grains of the genotypes ranged from 66.19% to 69.81%, with the highest contents for the line MNC00-595F-27 and the cultivar Vagem Roxa-THE, which differed significantly ($p < 0.05$) from the genotypes MNC00-595F-27 and BRS-Tumucumaque. These moisture contents were consistent with those reported by Melo et al (2017), who analyzed cooked immature grains of four cowpea cultivars and observed an average moisture content of 65.81%.

The lines MNC05-847B-123 and MNC00-595F-27 did not differ from each other in relation to the ash content in the raw immature grains; however, the values differed significantly ($p < 0.05$) from those of the cultivars BRS-Tumucumaque and Vagem Roxa-THE (the ash contents in the raw immature grains of cultivars BRS-Tumucumaque and Vagem Roxa-THE did not differ each other). The lines had higher ash content (0.94-1.14 g 100 g^{-1}), values, lower than those observed by Melo et al. (2017) (1.56-1.66 g 100 g^{-1}) upon evaluating the immature grains of four cowpea cultivars. The ash content predicts the concentration of minerals in the analyzed product. The differences between the results obtained in the present study and in the works cited can be explained by the fact that the analyzes in some of the studies were carried out on green grains, in addition to the genetic variation, which is intrinsic to each genotype.

The genotypes did not differ in terms of ash content in cooked immature grains, ranging from 0.54 to 0.83 g 100 g^{-1}, agreeing with the results obtained by Melo et al. (2017), upon evaluating the cooked grains of cowpea cultivars BRS-Aracê, BRS-Guariba, BRS-Tumucumaque, and BRS-Xiquexique.

The reduction in ash content after cooking can be attributed to the loss of minerals through diffusion in the water used during the heat treatment (BARAMPANA; SIMARD, 1994).

The lipid content varied from 0.44 to 0.93 g 100 g^{-1} in raw immature grains. The line MNC00-595F-27 differed significantly ($p < 0.05$) from the other genotypes in its lipid content, presenting the highest lipid content. Melo et al. (2017) observed high lipid contents (1.30-2.19 g 10g^{-1}) in raw immature grains upon evaluating four cowpea cultivars. Regarding the lipid content in cooked immature grains, the cultivar BRS-Tumucumaque differed significantly ($p < 0.05$) from the other genotypes, presenting the highest content (0.27 g 100 g^{-1}), which was lower than that found by Melo et al. (2017) (1.55-2.31 g 100 g^{-1}). The decrease in lipid content with cooking can be attributed to a interference during the analysis caused by the formation of a lipid-protein complex (RAMÍREZ -CÁRDENAS; LEONEL; COSTA, 2008).

The lines MNC05-847B-123 and MNC00-595F-27 differed significantly ($p < 0.05$) from the other genotypes in their protein contents in raw immature grains. Araújo et al. (2021) upon evaluating the immature grains of 16 cowpea genotypes observed much lower protein contents (2.72-15.15 g 100 g^{-1}) than those obtained in the present work (8.13-9.12 g 100 g^{-1}). The genotypes did not differ in terms of cooked immature grains, which ranged from 8.90 to 10.13 g 100 g^{-1}, almost like what was found by Melo et al. (2017), which ranged from 9.30 to 11.61 g 100 g^{-1}.

The line MNC05-847B-123 and the cultivar BRS-Tumucumaque differed significantly ($p < 0.05$) from the other genotypes for the carbohydrate contents in raw immature grains. The line MNC05-847B-123 had the highest carbohydrate content (23.04 g 100 g^{-1}), which was lower than the carbohydrate contents observed by Melo et al. (2017) (27-29 g 100 g^{-1}) on evaluating raw immature grains of four cowpea cultivars. In relation to cooked immature grains, the genotypes did not differ from each other, varying from 21.13 to 23.34 g 100 g^{-1}, consistent with the results of Melo et al. (2017), (20.12-22.17 g 100 g^{-1}).

Regarding the TEV of raw immature grains, a variation of 123.69-132.73 kcal 100 g^{-1} was observed. The line MNC05 -847B-123 differed significantly ($p < 0.05$) from the other genotypes in its TEV. The TEV in the present study was lower than that observed by Melo et al. (2017) (159.33-170.91 kcal 100 g^{-1}) in raw immature grains of four cowpea cultivars. Considering the cooked immature grains, the genotypes MNC05-847B-123 and BRS-Tumucumaque differed significantly ($p < 0.05$) from the genotypes MNC00-595F-27 and Vagem Roxa-THE, ranging from 119.15 to 137.19 kcal 100 g^{-1}. The TEV verified in the present study was lower than that observed by Melo et al (2017) upon evaluating cooked immature grains of four cowpea cultivars, with the TEV ranging from 140.73 to 146.19 kcal 100 g^{-1}.

The differences observed in the proximate composition and TEV of immature grains of cowpea genotypes studied in the present study in relation to other research may be due to the genotype and environmental conditions (soil type) during plant development, in addition to the cultural treatments (GOMES; REIS; SILVA, 2012; BEZERRA et al., 2019).

Impact of cooking immature grains on the centesimal composition

After heat treatment, no differences were observed in moisture content; however, there was a reduction in the ash and lipid contents in the four evaluated cowpea genotypes. The protein content was not affected by cooking, except in the cultivar BRS-Tumucumaque, in which an increase in the content of this nutrient was observed. Melo et al. (2017), upon evaluating raw and cooked immature grains of the BRS-Tumucumaque cultivar, also observed a behavior similar to that of the present work. The increase in the protein content of bean grains is attributed to thermal processing, especially because of moist heat and due to the denaturation of antinutritional factors of a protein nature and, at the same time, due to the avoidance of considerable degradation of essential amino acids (RAMÍREZ-CÁRDENAS; LEONEL; COSTA, 2008).

Regarding carbohydrate content, cooking resulted in an increase of 6.5% in the line MNC00-595F-27; however, it did not affect the other genotypes. This result indicates that depending on the genotype, cooking can cause different physicochemical changes in the starch, either by affecting or not affecting the carbohydrate content in the cowpea grain.

The cooking affected the TEV, increasing its content by 3.36% and 4.08 in genotypes MNC05-847B-123 and BRS-Tumucumaque, respectively, and decreasing its content by 6.13% in the cultivar Vagem Roxa-THE. The results partially agree and disagree with statements of Bezerra et al. (2019). These authors had stated that the cooking process affects the nutrient composition of the cowpea genotypes, causing an increase in the moisture content and a decrease in the ash, lipid, protein, and carbohydrate contents and TEVs, compared to those in the raw grains, with these nutrients being transferred to the cooking broth.

The application of heat to immature cowpea grain reduced the most nutrients evaluated; however the contents may increase due to some intrinsic characteristic of the genotype present in the grain. Thus, it is essential and beneficial in the case of legumes, as it enables their consumption and increases the bioavailability of proteins through the inactivation of anti-nutritional, in addition to contributing to the improvement of smell, taste and texture of the immature grains for the consumers.

Composition of minerals in raw and cooked grains

The results referring to the analysis of minerals in the raw and cooked immature grains of four cowpea genotypes are shown in Table 3.

The line MNC05-847B-123 differed significantly ($p < 0.05$) from the other genotypes in the Ca content in its raw immature grains, ranging from 33.46 to 45.50 mg 100 g^{-1}. Regarding the Ca content in cooked immature grains, the lines MNC05-847B-123 and MNC00-595F-27 differed significantly ($p < 0.05$) from the cultivars BRS-Tumucumaque and Vagem Roxa-THE, ranging from 64.00 to 71.67 mg 100 g^{-1}. These contents were lower than those observed by Carvalho et al. (2022) in a study on immature grain in ten cowpea genotypes, with values ranging from 60.00 to 100.00 mg 100 g^{-1}. Costa (2014), analyzing the Ca content in cooked immature grains of four cowpea cultivars, observed contents ranging from 52.99 to 91.4 mg 100 g^{-1}, higher than that obtained in the present study.

Table 3. Means of mineral contents in the raw and cooked immature grains of four cowpea genotypes.

Mineral (mg 100 g^{-1})	Process (wet base)	MNC05-847B-123	MN00-595F-27	BRS-Tumucumaque	Vagem Roxa-THE
Ca	Raw	33.46 ± 0.02 cB	39.02 ± 0.05 bB	34.17 ± 0.03 cB	45.50 ± 0.05 aB
	Cooked	71.00 ± 0.03 aB	71.67 ± 0.05 aB	64.67 ± 0.05 bB	64.00 ± 0.05 bB
Mg	Raw	63.77 ± 0.05 aA	53.86± 0.02 bB	43.23 ± 0.11 cB	67.85± 0.05 aB
	Cooked	69.00 ± 0.11bB	68.33 ± 0.05bB	69.33 ± 0.03bB	178.67 ± 0.16aA
P	Raw	181.00 ± 0.05 bA	188.00 ± 0.06 aA	172.00 ± 0,02 cA	184.00± 0.12 bB
	Cooked	160.67 0.24± cB	173.67 ± 0.20 bB	156.67 ± 0.10 cB	191.00 ± 0.06 aB
K	Raw	497.00 ± 0,07 aA	497.00 ± 0.04 aA	457.00± 0.038 bA	453.00 ± 0.08 bA
	Cooked	324.70 ± 1.78 aB	267.67 ± 0.05 aB	231.33 ± 0.18 bB	204.33 ± 0.73 bB
Zn	Raw	1.56 ± 0.11 bA	1.63 ± 0.17 aA	1.53 ± 0.15 bA	1.35 ± 0.34 cA
	Cooked	1.38 ± 1.60 bB	1.54 ± 2.36 aB	1.40 ± 0.27 bB	1.12 ± 1.49 cB
Fe	Raw	2.16 ± 0.46 aB	2.07 ± 0.20 bB	2.17 ± 0,56 aB	2.17 ± 0.35 aB
	Cooked	5.62 ± 3.10 aA	5.65 ± 1.92 aB	5.59 ± 1.95 bB	5.62 ± 2.35 aB
Mn	Raw	0.63 ± 0.45 aB	0.57± 0.27 bB	0.55 ± 0.33 bB	0.58 ± 0.04 bB
	Cooked	0.72 ± 1.18 aB	0.71 ± 0.40 aB	0.76 ± 0.17 aB	0.78 ± 0.64 aB

Mean of three replicates + standard deviation. Means followed by the same lowercase letter in the row and uppercase in the column do not differ significantly as analyzed using the Tukey's test and Student's t-test ($p < 0.05$), respectively.

The genotypes MNC05-847B-123 and Vagem Roxa-THE differed significantly ($p < 0.05$) from the genotypes MNC00-595F-27 and BRS-Tumucumaque in the Mg content in its raw immature grains, which ranged from 43.23 to 67.85 mg 100 g^{-1}, lower than the contents observed by Carvalho et al. (2022), which ranged from 160 to 200 mg 100 g^{-1}. As for cooked immature grains, the cultivar Vagem Roxa-THE differed significantly ($p < 0.05$) from the other genotypes, with a content of 178.67 mg 100 g^{-1}, lower than those observed by Costa (2014), who observed values from 110.14 to 147.85 mg 100 g^{-1} upon evaluating immature grains of four cowpea cultivars.

The line MNC00-595F-27 differed significantly ($p < 0.5$) from the other genotypes in the P content in its raw immature grains, with a value of 188.00 mg 100 g^{-1}, which was lower than those observed by Carvalho et al. (2022), who observed values from 425 to 540 mg 100 g^{-1}. In cooked immature grains, the cultivar Vagem Roxa-THE differed significantly ($p < 0.05$) from the other genotypes, with the highest content (191.00 mg 100 g^{-1}); however, the value was lower than that observed by Costa (2014), also in cooked immature grains of four cowpea cultivars, where the values ranged from 341.78 to 447.57 mg 100 g^{-1} were obtained.

The lines MNC05-847B-123 and MNC00-595F-27 differed significantly ($p < 0.05$) from the cultivars BRS-Tumucumaque and Vagem Roxa-THE in the K contents in their raw immature grains, with the highest content being 497.00 mg 100 g^{-1}; however, the values were lower than those observed by Carvalho et al. (2022), who observed values ranging from 970.00 to 1,156.00 mg 100 g^{-1}. Similarly, the K contents in the cooked immature grains of the lines were higher than those of the cultivars, with a higher content for the line MNC05-847B-123 (324.70 mg 100 g^{-1}); however, these values were lower than those observed by Costa (2014), who reported values ranging from 711.84 to 1,001.96 mg 100 g^{-1}.

The line MNC00-595F-27 had the highest Zn content (1.63 mg 100 g^{-1}) in the raw immature grains and differed significantly ($p < 0.05$) from the other genotypes, which together presented a variation of 1.35 to 1.63 mg 100 g^{-1}, lower than the value observed in the best cultivar (AUA2) in the study carried out by Carvalho et al. (2022), which was 5.5 mg 100 g^{-1}. Likewise, regarding the Zn content in cooked immature grains, the line MNC00-595F-27 was superior to the other genotypes, with a content of 1.54 mg 100 g^{-1}, which is lower than the values observed by Costa (2014), who observed a variation of 4.36 to 5.06 mg 100 g^{-1} in a study with four cowpea cultivars.

The genotypes MNC05-847B-123, BRS Tumucumaque and Vagem Roxa-THE did not differ from each other; however, it differed significantly ($p < 0.05$) from the line MNC00-595F-27 in terms of the Fe content in the raw immature grains, which ranged from 2.07 to 2.17 mg 100 g^{-1}, lower than that value observed in the best cultivar (AUA2) in the study carried out by Carvalho et al. (2022) (7.09 mg 100 g^{-1}). As for the Fe content in cooked immature grains, the genotypes MNC05-847B-123, MNC00-595F-27 and Vagem Roxa-THE did not differ from each other; however, they differed significantly ($p < 0.05$) from the cultivar BRS-

Tumucumaque, which together ranged from 5.59 to 5.65 mg 100 g^{-1}, similar to that observed by Costa (2014), who obtained a variation of 5.55 to 6.44 mg 100 g^{-1} in a study with cooked immature grains of four cowpea cultivars.

The line MNC05-847B-123 deferred significantly ($p < 0.05$) from the other genotypes for the Mn content in raw immature grains, which together ranged from 0.55 to 0.63 mg 100 g^{-1}. The variation was lower than those observed by Carvalho et al. (2022), which obtained variation from 1.36 to 2.13 mg 100 g^{-1}. As for the Mn content in cooked immature grains, the genotypes did not differ each other for this mineral and ranged from 0.71 to 0.78 mg 100 g^{-1}, lower than those observed by Costa (2014), evaluating the cooked immature grains of four cultivars, which ranged from 1.40 to 1.76 mg 100 g^{-1}.

Impact of cooking immature grains on mineral content

After cooking, the Ca, Mg, Fe and Mn contents observed in the best genotypes increased by an average of 41% (Vagem Rocha-THE), 12% (MNC05-847B-123 and Vagem Roxa-THE), 158% (MNC05- 847B-123, BRS-Tumucumaque and Vagem Roxa-THE), and 14% (MNC05-847B-123), respectively. Increased Ca contents after cooking were also observed by Costa (2014) on evaluating immature grains of four cowpea cultivars; however, these authors observed a decrease in Mg content after cooking, an observation different from that observed in the present study. Some minerals, such as Ca and Fe, when present in raw grains, may remain in a form that is not fully available or complexed with other nutrients, such as proteins or anti-nutritional factors (phytic acid, tannins, phenolic acids), which after cooking can be decomplexed and released.

The P content decreased by an average of 9% in the genotypes MNC05-847B-123, MNC00-595F-27 and BRS-Tumucumaque; however, it increased by 3.80% in the cultivar Vagem Roxa-THE. Similar results were observed by Costa (2014) upon evaluating immature grains of four cowpea cultivars, wherein for one cultivar, there was an increase and for the others, a reduction in P content. This difference in behavior in the cultivar Vagem Roxa-THE for the P content in terms of cooking, compared to the other genotypes, is probably due to an intrinsic genetic factor, where in this cultivar, cooking contributed to releasing more K, unlike the other genotypes, where the cooking led to losses of this mineral.

Cooking reduced the K and Zn contents of the best genotypes by an average of 45% (MNC05-847B-123 and MNC00-595F-27) and 5.5% (MNC00-595F-27). Similar results were observed by Costa (2014) upon evaluating immature grains of four cowpea cultivars, where there was a reduction in the contents of these minerals after cooking. In another study with raw and cooked grains, cooking reduced the protein, K, Ca, Fe, and Zn contents in the grains of 24 cowpea genotypes (SILVA et al., 2016). The reduction in P, K, and Zn contents was probably due to the dissolution of these minerals in the cooking water (BRIGIDE; CANNIATTI-BRAZACA, 2011). Notably, in this study, the cooking broth was not considered for the analysis of macro and microminerals.

Despite the losses after cooking, the studied cowpea genotypes retained relevant contents for the analyzed minerals, especially for Zn, which had the lowest losses, in relation to the other minerals, after thermal processing. The line MNC00-595F-27 showed the lowest loss in Zn content after cooking. According to Silva et al. (2016), possibly, the short cooking time of cowpea grains provided a smaller reduction in nutritional contents than that in raw and cooked grains.

The chemical composition of foods of plant origin is influenced and controlled by intrinsic and extrinsic factors such as the genetic characteristics of the plant, soil fertility, and the growing environment (BEZERRA et al., 2019). In addition, the processing conditions employed, such as the amount and temperature of water and the time of contact between it and beans are factors that may favor the migration of minerals to the broth (OLIVEIRA et al., 2008; RAMÍREZ-CÁRDENAS; LEONEL; COSTA, 2008). Thus, on the one hand, cooking causes loss of nutrients, on the other hand, according to Bezerra et al. (2019), cooking contributes to increasing the bioavailability of proteins and minerals by decreasing or eliminating antinutritional compounds, such as phytates, tannins and others.

CONCLUSION

The cowpea genotypes MNC05-847B-123 and BRS-Tumucumaque present faster immature grain cooking than commercial controls. Cooking did not affect the levels of moisture, proteins, carbohydrates, and TEV in MNC00-595F-27; however, it reduced the levels of ash, lipids, and TEV in Vagem Roxa-THE and increased the protein content in BRS-Tumucumaque, carbohydrate content in MNC00-595F-27, and the TEVs in MNC05-847B-123 and BRS-Tumucumaque. Cooking reduced the P, K, and Zn contents, with the reduction in Zn content being the least with thermal processing, and increased the Ca, Mg, Fe, and Mn contents. The lines MNC05-847B-123 and MNC00-595F-27 even with losses, after the thermal processing of the immature grain, presented nutritional potential as cultivars for the green-bean market.

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REFERENCES

AOAC - Association of Official Analytical Chemists. **Official Methods of Analysis of AOC International**. 21. ed. Rockville: AOAC International, 2019.

AQUINO, D. A. L.; SANTOS, C. A. F. S.; SILVA, D. O. M. Phenotypic variability of cowpea genotypes for immature seed harvesting. **Pesquisa Agropecuária Tropical**, 51: 1-8, 2021.

ARAÚJO, L. B. R. et al. Influence of the environment and production components on the protein content of green cowpea grain. **Revista Ciência Agronômica**, 52: 1-9, 2021.

BARAMPANA, Z.; SIMARD, R. E. Oligosaccharides, antinutritional factors and protein digestibility of dry beans as affected by processing. **Journal of Food Science**, 59: 833-838,1994.

BEZERRA, J. M. et al. Composição química de oito cultivares de feijão-caupi. **Revista Verde**, 14: 41-47, 2019.

BRIGIDE, P.; CANNIATTI-BRAZACA, S. G. Avaliação dos efeitos da cocção e irradiação na composição do feijão carioca (*Phaseolus vulgaris* L.). **Alimentos e Nutrição**, 22: 97-102, 2011.

CARVALHO, M. et al. Cowpea immature pods and grains evaluation: an opportunity for different food sources. **Plants**, 11: 1-15, 2022.

CONAB - Companhia Nacional de Abastecimento. **Acompanhamento da safra brasileira: grãos, safra 2021/2022, 12º levantamento, setembro de 2022**. 2022. Brasília, DF: CONAB, v. 9, n. 12. Disponível em: https://www.conab.gov.br/info-agro/safras/graos>. Acesso em: 3 fev. 2023.

COSTA, N. Q. **Características nutritivas e sensoriais de formulações de baião- de-dois elaboradas a partir de arroz integral e feijão-caupi biofortificados**. 2014. 102 f. Dissertação (Mestrado em Ciência de Alimentos: Área de Concentração em Alimentos e Nutrição) - Universidade Federal do Piauí, Teresina, 2014.

CRUZ, C. D. Genes Software - extended and integrated with the R, Matlab and Selegen. **Acta Scientiarum**, 38: 547-552, 2016.

FAOSTAT - **Statitical databases**. Disponível em: <https://www.fao.org/faostat/en/#data/QCL>. Acesso em: 7 mai. 2022.

FREIRE FILHO, F. R. et al. A cultura: aspectos socioeconômicos. In: VALE, J. C.; BERTINI, C.; BORÉM, A. (Eds.). **Feijão-caupi: do plantio à colheita**. Viçosa, MG: Editora UFV, 2017. v. 1, cap. 1, p. 9-34.

GOMES, G. M. S.; REIS, R. C.; SILVA, C. A. D. T. Obtenção de farinha de feijão-caupi (*Vigna unguiculata* L. Walp). **Revista Brasileira de Produtos Agroindustriais**, 14: 31-36, 2012.

MARTINS, M. P. S. C. et al. Characterization of cowpea cultivars for grain size, color, and biofortification. **Revista Caatinga**, 38: 207-214, 2023.

MATTSON, S. The cookability of yellow peas: a colloid-chemichal and biochemical study. **Acta Agriculturae Suecana**, 2: 185-231, 1946.

MEKONNEN, T. H. et al. Breeding of vegetable cowpea for nutrition and climate resilience in Sub-Saharan Africa: progress, opportunities, and challenges. **Plants**, 11: 1-23, 2022.

MELO, N. Q. C. et al. Chemical characterization of green grain before and after thermal processing in biofortified cowpea cultivars. **Revista Ciência Agronômica**, 48: 811-816, 2017.

MOTA, C. et al. The effect of cooking methods on the mineral content of quinoa (*Chenopodium quinoa*), amaranth (*Amaranthus* sp.) and buckwheat (*Fagopyrum esculentum*). **Journal of Food Composition and Analysis**, 49: 57-64, 2016.

NTATSI, G. et al. The quality of leguminous vegetables as influenced by preharvest factors. **Scientia Horticulturae**, 232: 191-205, 2018.

OLIVEIRA, V. R. et al. Qualidade nutricional e microbiológica de feijão (*Phaseolus vulgaris* L.) cozido com ou sem água de maceração. **Ciência e Agrotecnologia**, 32: 1912-1918, 2008.

PINHEIRO, E. M. **Caracterização química, poder antioxidante e efeito do cozimento de genótipos de feijão-caupi**. 2013. 65 f. Dissertação (Mestrado em Ciência de Alimentos: Área de Concentração em Alimentos e Nutrição) - Universidade Federal do Piauí, Teresina, 2013.

RAMÍREZ-CÁRDENAS, L.; LEONEL, A. J.; COSTA, N. M. B. Efeito do processamento doméstico sobre o teor de nutrientes e de fatores antinutricionais de diferentes cultivares de feijão comum. **Ciência e Tecnologia de Alimentos**, 28: 200-213, 2008.

ROCHA, M. M. et al. Adaptabilidade e estabilidade de genótipos de feijão-caupi quanto à produção de grãos frescos, em Teresina-PI. **Revista Científica Rural**, 14: 40-55, 2012.

ROCHA, M. M.; SILVA, K. J. D.; MENEZES JUNIOR, J. A. Cultivares. In: DOVALE, J. C.; BERTINI, C.; BORÉM, A. (Eds.). **Feijão-caupi: do plantio à colheita**. Viçosa, MG: Editora UFV, 2017. v. 1, cap. 6, p. 113-142.

SAS - Statistical Analysis System. **SAS/STA User's Guide: statistics**. Version 9.1. edition. Cary NC: SAS Inc., 2012.

SILVA, C. O.; TASSI, E. M. M.; PASCOAL, G. B. **Ciência dos alimentos: princípios de bromatologia**. 1. ed. Rio de Janeiro, RJ: Rubio, 2016. 248 p.

SILVA, M. B. O. et al. Technological quality of grains of common beans selected genotypes from the carioca group. **Semina: Ciências Agrárias**, 37: 1721-1732, 2016.

SILVA, E. F. et al. Avaliação de cultivares de feijão-caupi irrigado para produção de grãos verdes em Serra Talhada-PE. **Revista Caatinga**, 26: 21-26, 2013.

SOUSA, J. L. M. et al. Potencial de genótipos de feijão-caupi para o mercado de vagens e grãos verdes. **Pesquisa Agropecuária Brasileira**, 50: 392-398, 2015.

SOUSA, T. J. F. et al. Simultaneous selection for yield, adaptability, and genotypic stability in immature cowpea using REML/BLUP. **Pesquisa Agropecuária Brasileira**, 54: 1-9, 2019.

VIEIRA, M. M. S.; BEZERRA, J. M.; SANTOS, A. F. Avaliação dos compostos bioativos e capacidade antioxidante em cultivares de feijão-caupi (*Vigna unguiculata* L.) imaturo cru, cozido e seus caldos de cocção. **Research, Society and Development**, 10: 1-11, 2021.

WAINAINA, I. et al. Thermal treatment of common beans (*Phaseolus vulgaris* L.): Factors determining cooking time and its consequences for sensory and nutritional quality. **Comprehensive Reviews in Food Science and Food Safety**, 20: 1-29, 2021.

WATT, B.; MERRILL, A. L. **Composition of foods: raw, processed, prepared**. Washington, DC: United States Departament of Agriculture, 1963. v. 1, 190 p.