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Proximate composition, minerals, tannins, phytates and cooking quality of commercial cowpea cultivars

Composição centesimal, minerais, taninos, fitatos e qualidade de cozimento de cultivares comerciais de feijão-caupi

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ABSTRACT - Cowpea is a socioeconomically important legume in the Northeast region of Brazil, and the most grown and consumed type of bean, representing the main source of low-cost vegetable protein for rural and urban populations in this region. The objective of this work was to characterize the proximate composition, minerals, tannins, phytic acid, and cooking quality of whole grains of cowpea from the commercial cultivars BRS Aracê, BRS Inhuma, and BRS Xiquexique. Grain samples of the cultivars were ground in a zirconium ball mill and the flour was used for analysis. The proximate composition was carried out according to the AOAC methodology. The minerals were determined by nitro-perchloric digestion and reading in a flame atomic absorption spectrophotometer. The anti-nutritional factors tannins and phytic acid were determined by extraction and reading in a spectrophotometer. Cooking quality was assessed using an electric pressure cooker and then a Mattson cooker. A completely randomized experimental design was used, with three treatments (cultivars) and three replications. The data were subjected to analysis of variance and the means were compared by the Tukey's test ($p<0.05$). The cowpea cultivars showed significant differences ($p<0.05$) for most characteristics evaluated and were similar in terms of ash, lipids, total dietary fiber, and most macrominerals. The results showed that grains of the cultivars BRS Aracê and BRS Xiquexique are excellent sources of dietary fiber, proteins, and minerals and present high cooking quality, while grains of the cultivar BRS Inhuma stood out regarding carbohydrates, soluble dietary fibers, total energetic value, and low levels of factors, anti-nutritional tannins and phytic acid.

Keywords: *Vigna unguiculata*. Nutritional quality. Mineral composition. Anti-nutritional factors. Fast cooking.

RESUMO - O feijão-caupi é uma leguminosa de grande importância socioeconômica na região Nordeste do Brasil, sendo o tipo de feijão mais cultivado e consumido, representando a principal fonte de proteína vegetal de baixo custo das populações rural e urbana dessa região. O objetivo deste trabalho foi caracterizar a composição centesimal, minerais, taninos, ácido fítico e a qualidade de cozimento dos grãos integrais das cultivares de feijão-caupi BRS Aracê, BRS Inhuma e BRS Xiquexique. A composição centesimal foi determinada de acordo com a metodologia AOAC. Os minerais foram determinados por digestão nitro-perclórica e leitura em espectrofotômetro de absorção atômica de chama. Os fatores antinutricionais taninos e ácido fítico foram determinados por extração e leitura em espectrofotômetro. A qualidade do cozimento foi avaliada usando uma panela de pressão elétrica e, em seguida, o cozedor de Matsson. Foi utilizado o delineamento inteiramente casualizado (DIC), com três tratamentos (cultivares) e três repetições. Os dados foram submetidos à análise de variância e as médias comparadas pelo teste de Tukey ($p<0,05$). As cultivares apresentaram diferenças significativas ($p<0,05$) para a maioria das características avaliadas e similares para os teores de cinzas, lipídeos, fibra alimentar total e a maioria dos macrominerais. As cultivares BRS Aracê e BRS Xiquexique representam excelentes fontes de fibras dietéticas, proteínas e minerais, além de alta qualidade de cozimento, enquanto a cultivar BRS Inhuma destacou-se em carboidratos, fibras alimentares solúveis, valor energético total e baixos teores dos fatores antinutricionais analisados.

Palavras-chave: *Vigna unguiculata*. Qualidade nutricional. Composição mineral. Fatores antinutricionais. Cozimento rápido.

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INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is an important crop as a food and as a generator of employment and income in the Northeast region of Brazil, mainly in the states of Ceará, Pernambuco, and Piauí. Cowpea grains are very nutritious and a staple food for rural and urban populations in the Northeast region. Brazil is the third largest cowpea producing country in the world. The crop occupied an area of 1,349,600 ha in the 2020/2021 agricultural year, with a production of 625,200 tons and a yield of 463 kg ha^{-1} (CONAB, 2021). The low production cost and possibility of high yields have been the main attractions for the growth of cowpea in Brazil (SILVA; ROCHA; MENEZES-JÚNIOR, 2016).

Cowpea is an excellent source of proteins and carbohydrates and has high dietary fiber contents, vitamins, and minerals and low lipid content (FROTA et al., 2010; BEZERRA et al., 2019). Characterization of variation for proximate and mineral composition has been performed in several recent studies involving several cowpea genotypes (ALUDI; ASANTE; MENSAH, 2020; DIAS-BARBOSA et al., 2021; FREITAS et al., 2022).

Despite the high nutritional and functional value, cowpea grains have anti-nutritional compounds that reduce the bioavailability of proteins and minerals, such as phytic acid and condensed tannins (GONÇALVES et al., 2020; KHALID; ELHARDALLOU, 2016). Domestic processing, including stripping, soaking in water, and cooking, decreases anti-nutritional compounds (DIOUF et al., 2020).

One of the main limitations to increases in consumption of cowpea is the longer cooking time, which leads to losses in nutrients and useful time and greater energy consumption (firewood or gas) and increases in greenhouse gas emission by increasing wood burning, mainly in African countries; however, a rapid cooking may provide a highly nutritious food and less preparation time and energy consumption (ADDY et al., 2020; FREITAS et al., 2022). The inclusion of cooking quality in the evaluation of cultivars contributes to improve culinary quality and consumer acceptance (CARVALHO et al., 2017).

The easy access to this type of food by low-income communities makes it an excellent complementary food, especially for children and adolescents. Thus, the objective of this work was to characterize the proximate composition, minerals, tannins, phytic acid, and cooking quality of whole grains of cowpeas from the commercial cultivars BRS Aracê, BRS Inhuma and BRS Xiquexique.

MATERIAL AND METHODS

Obtaining of cowpea grains

Grain samples from three commercial cowpea cultivars (BRS Aracê, BRS Inhuma and BRS Xiquexique) were developed and provided by the Embrapa Meio-Norte, in Teresina, Piauí, Brazil. The cultivars were grown in the Embrapa Meio-Norte experimental field in the second half of 2020 under irrigated conditions. After harvesting, grain samples of each cultivar were used to carry out nutritional and cooking analyses.

Sample preparation

The cowpea grain samples were selected, eliminating defective or spoiled grains. They were then ground in a semi-industrial electric grinder (Tecnal model TE-651/2-T). The cowpea flour (0.5 mesh) was stored in hermetically sealed polyethylene bags under refrigeration (8°C) until the analysis.

Proximate composition

Proximate composition (moisture, ash, lipids, proteins, dietary fiber, and carbohydrates) and total energy value were evaluated at the Laboratory of Bromatology and Food Biochemistry of the Nutrition Department of the Federal University of Piauí, in Teresina, PI, Brazil.

Moisture contents were determined by gravimetry in an oven at 105 °C (AOAC, 2012). One gram of the homogenized sample was weighed in a previously weighed porcelain crucible. The samples were then placed in an oven at 105 °C for 4 hours and then transferred to a desiccator and kept for 30 minutes. Moisture contents (%) were calculated by the following formula: $Moisture\ content = (100 \times N) / P$, where N is the moisture wight (weight lost in g) and P is sample weight (g).

Ash contents were determined by incineration in a muffle furnace at 550 °C for 4 hours, according to the AOAC (2012). Samples of 1 g were placed in porcelain crucibles in a muffle furnace and calcined at 550 °C for 4 hours. Mineral matter was determined by the difference between initial and final weights of the crucibles.

Total lipids (%) were determined in samples subjected to hot extraction by hexane 1:5 (m v^{-1}) in a Soxhlet system for 8 hours. Lipids were collected in a beaker and left in an exhaust hood. After hexane dissipation, the beakers were placed in a drying oven for approximately 30 minutes; the extracted lipid material was then quantified, and the percentage was calculated in relation to the initial dry sample.

Protein contents in the samples were obtained by the Micro-Kjeldahl method (AOAC, 2012), through the product of the measured nitrogen using the protein conversion factor (6.25). The total amount of nitrogen was determined using a standard curve obtained by increasing concentrations of ammonium sulfate.

Dietary fiber contents were determined by enzymatic gravimetry (AOAC, 2012), carried out by treatments of the samples with a phosphate buffer solution at the temperature range of 95 to 100 °C, in which soluble carbohydrates were solubilized. The sample was treated with α-amylase to promote starch gelatinization, followed by addition of protease enzyme to denature the proteins; the treatment was finished with amyloglucosidase enzyme to remove the starch. In this process, a mixture of soluble fiber in the aqueous phase and precipitated insoluble fiber was obtained, composing the total dietary fiber. Filtration was carried out in a tared sintered glass crucible; the crucible was oven-dried, weighed, and then placed in a muffle furnace to determine ash contents. The filtrate was treated with 95% ethyl alcohol solution to precipitate the soluble fiber. The total dietary fiber contents were then calculated by the total residue obtained minus the sum of protein plus ash contents.

Carbohydrate contents were determined by the difference from the other constituents of the proximate composition (moisture, ash, proteins, fibers, and lipids) (AOAC, 2012).

Total energy value

Total energy value (TEV) was evaluated at the Laboratory of Bromatology and Food Biochemistry of the Nutrition Department of the Federal University of Piauí, in Teresina, PI, Brazil. TEV was determined according to the Normative Instruction no. 75 of 2020 (BRASIL, 2020), using the Atwater conversion factors: 4 kcal g^{-1} for proteins, 4 kcal g^{-1} for carbohydrates, and 9 kcal g^{-1} for lipids.

Minerals

Mineral phosphorus (P), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), and selenium (Se) were evaluated at the Bromatology Laboratories of Embrapa Meio-Norte, in Teresina, PI, Brazil, and iron (Fe), zinc (Zn) and selenium (Se) were evaluated at the Laboratory of Physical-Chemical and Mineral Analysis of the Embrapa Agroindústria de Alimentos, in Rio de Janeiro, RJ, Brazil.

P contents were determined by colorimetry, according to Silva and Queiroz (2002). A 200 mg sample was transferred to a digestion tube, 5 mL of nitro-perchloric solution was added, and the tube was taken to a digester block at 200 °C for 2 hours. In a test tube, 200 µL of the extract solution was added, together with 8.4 mL of Milli-Q water, 1.0 mL of acidic ammonium molybdate solution, and 400 µL of ascorbic acid solution. The solution was homogenized in a shaker; after five minutes, a blue color was expected to appear. The readings were carried out in a UV-VIS spectrophotometer, at a wavelength of 725 nanometers, using a quartz cuvette to read the solutions. The blank was read with distilled water to subtracted it from the direct reading of the equipment. The absorbance readings obtained were applied in the formula: *P = (0.2 x Reading/Sample Weight) / 10000*, where 0.2 is the factor obtained from the calibration curve.

Na and K contents were determined by the flame photometry method, according to Silva and Queiroz (2002): 2 mL of the extract and 2 mL of Milli-Q water were added to a test tube, and homogenized; the blank, standard, and samples, were then read directly in the flame photometer. The equipment was adjusted and calibrated with standard solutions of sodium and potassium before the readings.

Ca, Mg, Mn, and Cu contents were determined by the flame atomic absorption spectrophotometry method, according to Silva and Queiroz (2002): 200 µL of the extract, 3.5 mL of lanthanum, and 3.3 mL of Milli-Q water were added to a test tube, homogenized in a shaker, and read in the atomic absorption spectrum, previously selecting the specific wavelength of each element in the software of the device. A standard calibration curve was made for the reading of each element in the device.

Fe, Zn, and Se contents were determined by the inductively coupled plasma optical emission spectrometry method – ICP-OES (Optima 4300DV, Perkin Elmer, Norwalk, USA): 0.5 g of each sample was placed in a microwave tube and 2 mL of 30% (v v^{-1}) hydrogen peroxide (H_2O_2) was added to each tube and kept covered overnight for digestion. Then, 3 mL of concentrated nitric acid (HNO_3) were added to each tube; after two hours, this material was subjected to heating in a cavity microwave apparatus, according to the standard operating procedure (SOP) LMIN-008, I. 07, and digested at 1200 W, temperature at 200 °C, and pressure of 120 psi. Temperature and pressure were maintained for five minutes. After complete digestion, the tubes were removed from the apparatus, kept in a hood to cool, and opened after 30 minutes. After resting for 15 minutes, they were slowly filtered in a filter paper and adjusted to 25 mL. The readings were then carried out in the ICP-OES, according to the SOP of Embrapa LMIN-026, rev. 01.

Cooking quality

Cooking quality was evaluated using the methodology proposed by Carvalho et al. (2017), with adaptations for cowpea (FREITAS et al., 2022). Two samples of 50 grains of each genotype were placed in organza bags and identified. Two bags were prepared per genotype, (two replicates). The bags were placed in distilled water for 60 minutes. The bags were placed on the bottom of a 5-liter electric pressure cooker (Eletrolux). The water level used was 3/5 of the cooker capacity, keeping the water in which bags were soaked. The beans were cooked for 30 minutes. The soaking and cooking times were pre-established in preliminary tests.

The percentage of cooked grains was evaluated with the aid of a Mattson cooker (MATTSON, 1946). Samples of twenty-five cooked beans per cultivar were used and the pins were placed over the beans. The number of pins that completely pierced the grains was recorded. The higher the percentage of grains with fully perforated pins, the higher the cooking quality.

Statistical analysis

A preliminary analysis was carried out to assess the normality of residues of the data and presence of outliers. After verifying normality, the data were subjected to analysis of variance (F test) and the means were compared by the Tukey's test at 5% probability. Statistical analyzes were carried out using the SAS software (SAS, 2012).

RESULTS AND DISCUSSION

Proximate composition and total energy value

The grains of the cowpea cultivars showed significant differences ($p<0.05$) from each other for most quality characteristics analyzed (Table 1). The existence of variability among cultivars allows the selection of cultivars with better nutritional and functional attributes. Variability for nutrient contents in cowpea was also found by Aludi, Asante and Mensah (2020) and Bezerra et al. (2019), who analyzing the proximate composition of grains of several cowpea cultivars.

Table 1. Proximate composition and total energy value (TEV) of three cowpea cultivars.

Characteristic	BRS Aracê	BRS Inhuma	BRS Xiquexique
Moisture (%)	9.48a±0.10	8.60b±0.27	9.94a±0.52
Ashes (%)	3.84a±0.04	3.70a±0.07	3.87a±0.10
Lipids (%)	1.92a±0.31	2.04a±0.02	1.95a±0.09
Proteins (%)	25.72a±0.18	22.96b±0.50	23.74b±0.89
Carbohydrates (%)s	59.04b±0.48	62.68a±0.49	60.49b±0.90
Total dietary fiber (%)	16.14a±0.31	17.06a±0.76	16.87a±1.22
Soluble dietary fiber (%)	3.63b±0.14	4.94a±0.31	2.73c±0.70
Insoluble dietary fiber (%)	12.51b±0.21	12.12b±0.46	14.13a±0.51
TEV (Kg $100g^{-1}$)	356.30b±1.66	360.97a±1.39	354.48b±2.09

Means±standard deviation (n=3); means followed by the same letter in the rows are not statistically different from each other by the Tukey's test ($p<0.05$).

The cultivars BRS Aracê and BRS Xiquexique showed no significant differences from each other regarding grain moisture content (Table 1). BRS Inhuma presented lower moisture content (8.60%) than the other cultivars, indicating better stability and less susceptibility to deterioration of the grains or flours derived from them. This moisture content is lower than those reported by Bezerra et al. (2019) and López-Morales et al. (2020), who found means of 9.37% and 11.09%, when evaluating cowpea cultivars in Brazil and Mexico, respectively.

The evaluated cowpea cultivars showed no significant differences from each other regarding ash contents (3.70% to 3.87%) (Table 1). These contents are similar to those found by Rios et al. (2018), who evaluated the cowpea cultivars BRS Xiquexique, BRS Cauamé, BRS Guariba, BRS Novaera, and BRS Itaim and found ash contents of 3.65%, 3.43%, 3.53%, 2.06%, and 2.27%, respectively. It indicates that the samples used in the present work had higher inorganic residues, whose composition is mostly composed of minerals.

Legumes generally have low grain lipid contents compared to other macronutrients. The cultivars evaluated did not show differences from each other for lipid contents (1.92% to 2.04%), presenting contents higher than those reported by Biama et al. (2020), who found lipid contents varying from 0.13% to 0.60% for 15 cowpea cultivars in eastern Kenya, Africa.

Protein contents stood out among the characteristics used to evaluate the chemical composition of the BRS Aracê, BRS Inhuma and BRS Xiquexique cultivars, due to the high values found, which make them an excellent protein source to be consumed or added to various food products, especially for BRS Aracê, which presented a content of 25.72% (Table 1). Protein contents higher than 20%, as found in the present study, are considered high for legumes (ÇAKIR et al., 2019). Similar results were reported for several cowpea cultivars by Rios et al. (2018) and Bezerra et al. (2019), who found protein contents varying from 21.73% to 25.27% and from 20.66% to 26.06%, respectively.

The Resolution of the Collegiate Board of Directors (RDC) no. 269 of the Ministry of Health determines that the recommended daily intake (RDI) of proteins for adults is 50 grams day^{-1} (BRASIL, 2005). Considering that the protein content found for the cultivar BRS Aracê was 25.72 g 100 g^{-1}, the consumption of this cowpea cultivar meets 51.44% of the RDI.

The grain carbohydrate contents found for the cowpea cultivars were higher than those of the other components, especially for BRS Inhuma (62.68%), which significantly differed ($p<0.05$) from the others (Table 1), making it a good source of food energy. This is a similar value to the overall mean found by Rios et al. (2018), 62.38%, when evaluating five cowpea cultivars, including BRS Xiquexique, which presented a carbohydrate content of 61.02%, close to that found in the present work (60.49%).

The analyzed cowpea cultivars presented considerable total dietary fiber contents in their composition (16.14% to 17.06%), with no statistical differences from each other (Table 1). The contents found in the present work are higher than those found by Kirse and Karklina (2015), who evaluated dietary fiber in cowpea and found a variation of 12% to 14.80%. However, they were lower than those reported by Eashwarage, Herath and Gunathilake (2017), who found a variation of 13.07% to 21.35%. According to Cruz et al. (2021), fiber intake is mostly connected to in natura or minimally processed foods and the fiber density of this group is three-fold higher than that of ultra-processed foods; they pointed out that the rice and beans have the greatest contribution of fiber to Brazilians, reinforcing the nutritional importance of this typical cultural food combination in the country.

The evaluated cowpea cultivars stood out for presenting considerable levels of soluble (SDF) and insoluble (IDF) dietary fiber, mainly BRS Inhuma in SDF (4.94%) and BRS Xiquexique for IDF (14.13%) (Table 1). Garcia, Infante, and Rivera (2010) found lower SDF (0.89%) and higher IDF (15.5%) in the cowpea cultivars Unare and Tuy, in Venezuela.

Consumption of dietary fibers is connected to decreases in obesity due to their ability to form gels, which line the stomach wall, delay gastric emptying, increase the satiety feeling, and reduce constipation; insoluble dietary fibers increase fecal volume by retaining water, they reduce colonic transit time and risk of hemorrhoids and diverticulitis, prevent constipation and colon cancer, whereas soluble fiber increases fecal volume due to bacterial weight accumulation during its degradation, improves blood flow, increases water and sodium absorption, decreases pH, and acts on the metabolism of glucose and cholesterol, resulting in hypoglycemic and hypocholesterolemic effects (FARIAS et al., 2018; JAYATHILAKE et al., 2018).

The evaluated cowpea cultivars showed total energy values of 360.97 kcal 100 g^{-1} (BRS Inhuma), 356.30 kcal 100 g^{-1} (BRS Aracê), and 354.48 kcal 100 g^{-1} (BRS Xiquexique), without significant difference between the last two (Table 1), denoting the high energy value of whole grains of these cultivars. These values are consistent with those found by Bezerra et al. (2019) for grains of the cultivar Costela de Vaca (342.17 kcal 100 g^{-1}); Rios et al. (2018), for grains of the cultivar BRS Xiquexique (357.60 kcal 100 g^{-1}); and López-Morales et al. (2020), when evaluating the response to application of various forms and dosages of zinc sulfate in a cowpea cultivar in Mexico (330.4 kcal 100 g^{-1} to 338.90 kcal 100 g^{-1}).

Minerals

Cowpea is a potential source of minerals, in diversity and quantity, compared to other legumes used as food (Table 2). The evaluated cowpea cultivars showed no significant differences from each other regarding mineral phosphorus (P), calcium (Ca), magnesium (Mg) and potassium (K) contents. However, significant differences ($p<0.05$) were found between the cultivars for iron (Fe), zinc (Zn), manganese (Mn), and selenium (Se) contents.

Table 2. Minerals contents in grains of three cowpea cultivars.

Mineral	BRS Aracê	BRS Inhuma	BRS Xiquexique
P (mg 100 g^{-1})	405.00a±12.48	384.00a±15.71	408.66a±9.50
Ca (mg 10 g^{-1})	100.33a±4.16	106.33a±9.23	109.33a±2.30
Mg (mg 10 g^{-1})	226.33a±3.51	226.00a±3.46	229.66a±4.16
K (mg 10 g^{-1})	1450.66a±27.30	1385.66a±39.88	1475.00a±41.90
Fe (mg 100 g^{-1})	6.58a±0.04	5.67c±0.01	6.30b±0.04
Zn (mg 100 g^{-1})	3.92a±0.03	3.60b±0.03	3.92a±0.10
Mn (mg 100 g^{-1})	1.51a±0.02	1.23b±0.01	1.53a±0.02
Se (µg 100 g^{-1})	16.88b±1.05	77.05a±2.74	85.21a±10.26

Means±standard deviation (n=3); means followed by the same letter in the rows are not statistically different from each other by the Tukey's test ($p<0.05$).

Considering all minerals, K presented the highest contents in the cultivars, varying from 1385.66 to 1475.00 mg 100 g^{-1} (Table 2). These values are higher than those found by Gonçalves et al. (2020), who evaluated 18 cowpea cultivars and found K values ranging from 1033 to 1339 mg 100 g^{-1}.

The cowpea cultivars BRS Aracê and BRS Xiquexique significantly differed ($p<0.05$) from the BRS Inhuma cultivar for grain iron contents (Table 2). As expected, iron contents in biofortified cultivars (BRS Aracê and BRS Xiquexique) were higher than 6.0 mg 100 g^{-1}. According to Freire-Filho (2011), cultivars with iron content higher than 6.0 mg 100 g^{-1} are considered biofortified. Different results were reported by Rios et al. (2018) and Coelho et al. (2021), who found grain iron contents for the BRS Xiquexique cultivar below 6.0, 5.27, and 5.6 mg 100 g^{-1}, respectively. Some studies report that iron contents in cowpea range from 4.70 to 10.59 mg 100 g^{-1} (CARDONA-AYALA; ARAMENDIZ-TATIS; CAMACHO, 2021; DIAS-BARBOSA et al., 2021; GERRANO et al., 2019).

According to the RDC no. 269 of the Ministry of Health (BRASIL, 2005), the recommended daily intake (RDI) of iron is 14 mg for adults, 27 mg for pregnant women, 15 mg for lactating women, and 6 to 9 mg for children. According to the RDC no. 54 of the Ministry of Health (BRASIL, 2012), a food that supplies at least 15% of the RDI/100 g is considered as a source of minerals and a food that supplies at least 30% of the RDI/100 g is considered as a high-mineral content food.

Considering groups of healthy people with high iron demand (pregnant women, RDI = 27 mg), when 100 g of grains of cowpea grains contains 4.05 mg of iron (15% of RDI), it is considered as a source, and when it contains 8.10 mg of iron (30% of the RDI) it is considered as a high-iron content food.

Thus, the cultivar with the highest iron contents (BRS Aracê, Fe = 6.58 mg 100 g^{-1}) is a source of iron and can supply 24.37% of the daily iron intake of a pregnant woman. However, it is considered as a high-iron content food for adults, lactating women, and children, as it supplies their daily iron needs.

The cowpea cultivars BRS Aracê and BRS Xiquexique significantly differed ($p<0.05$) from BRS Inhuma regarding grain zinc and manganese contents; zinc contents were close to 4.0 mg 100 g^{-1} (3.92 mg 100 g^{-1}) and manganese were approximately 1.5 mg 100 g^{-1} (Table 2). The Mn contents found were similar to those found by Rios et al. (2018) for five cowpea cultivars. The differences found between the cowpea cultivars BRS Aracê and BRS Xiquexique and the cultivar BRS Inhuma were expected and corroborate that the first two are biofortified in Zn and BRS Inhuma is a non-biofortified cultivar for Zn

According to Freire-Filho (2011), cowpea cultivars with zinc contents higher than 40 mg kg^{-1} (4.0 mg 100 g^{-1}) are considered as biofortified. Thus, the cultivars BRS Aracê and BRS Xiquexique are excellent sources of zinc for strengthening immunity and fighting diseases in humans. These zinc contents are higher than those found in common bean cultivars (COELHO et al., 2021). Recent studies developed by Cardona-Ayala, Aramendiz-Tatis and Camacho (2021), Dias-Barbosa et al. (2021), Gerrano et al. (2019), and Silva et al. (2021a) involving a wide genetic diversity of cowpea presented zinc contents ranging from 3.16 and 6.50 mg 100 g^{-1}.

According to the RDC no. 269 of the Ministry of Health (BRASIL, 2005), the RDI for zinc is 7 mg for adults, 11 mg for pregnant women, 9.5 mg for lactating women, and 4.1 to 5.6 mg for children. Considering groups of healthy people with high zinc demand (lactating mothers, RDI = 9.5 mg) and the RDI percentages in the RDC no. 54 of the Ministry of Health (BRASIL, 2012), when 100 g of grains of the cowpea evaluated in the present study (BRS Aracê and BRS Xiquexique) contains 1.425 mg of zinc (15% of the RDI), it is considered as a source, and when it contains 2.85 mg of zinc (30% of the RDI) it is considered as a high-zinc content food. Thus, as the grain zinc contents of the cultivars were higher than 2.85 mg 100 g^{-1}, they are considered as a high-zinc content food, that can meet the daily zinc intake needs of adults, pregnant women, lactating women, and children.

The cowpea cultivars BRS Inhuma and BRS Xiquexique significantly differed ($p<0.05$) from BRS Aracê regarding grain selenium contents (77.05 and 82.21 µg 100 g^{-1}) (Table 2). These contents are lower than those found by Silva et al. (2021b), who evaluated the response of 29 cowpea genotypes to the application of sodium selenate and found a variation in grain Se contents of 54.97 to 246.21 µg 100 g^{-1}.

The RDI of selenium is 34 µg for adults, 30 µg for pregnant women, 35 µg for lactating women, and 17 to 21 µg for children, according to RDC no. 269 of the Ministry of Health (BRASIL, 2005). Considering groups of healthy people with high selenium demand (lactating mothers, RDI = 35 µg) and the RDI percentages in the RDC no. 54 of the Ministry of Health (BRASIL, 2012), when 100 g of grains of the cowpea evaluated in the present study contains 5.25 µg of selenium (15% of the RDI), it is considered as a source, and when it contains 10.50 µg of selenium (30% of the RDI) it is considered as a high-selenium content food. Thus, as the grain selenium contents in the cultivars were higher than 10.50 µg 100 g^{-1}, they are considered as a high-selenium content food and can meet the daily selenium intake needs of adults, pregnant women, lactating women, and children.

The grain Se contents in these cultivars are important for antioxidant processes and contribute to the proper functioning of the immune system and the thyroid. Moreover, it is a chemopreventive agent; an adequate intake of Se can reduce risks of cancer and may delay or reduce the prevalence of its recurrence (SILVA et al., 2021b).

Condensed tannins and phytic acid

Tannins are secondary metabolites in plants, classified into two types: hydrolysable (gallotannins, ellagitannins) and non-hydrolysable (condensed), which vary according to climate and geographic conditions, maturation, and other factors, presenting a varied chemical composition (BENEVIDES et al., 2011), as shown in Table 3.

Table 3. Condensed tannins and phytic acid contents of three cowpea cultivars.

Characteristic	BRS Aracê	BRS Inhuma	BRS Xiquexique
Condensed tannins (mg EC 10 g^{-1})	522.60a±184.50	153.60c±75.90	310.90b±169.50
Phytic acid (mg 100 g^{-1})	1016.00a±13.00	894.00b±33.00	987.00a±38.00

EC: Catechin Equivalents. Means±standard deviation; n=3; means followed by the same letter in the rows are not statistically different from each other by the Tukey's test ($p<0.05$).

The grains of the cowpea cultivars showed high condensed tannin concentrations, mainly the cultivar BRS Aracê (522.60 mg EC 100 g^{-1}) (Table 3). The ingestion of these compounds reduces the nutritional value of foods, as they interfere with digestibility, absorption or use of nutrients; when ingested in large quantities, they can cause adverse physiological effects, such as toxic reactions or decreases in bioavailability of minerals and essential amino acids. However, when these foods undergo certain processing, such as cooking, these anti-nutritional factors can be reduced or even eliminated (HIGASHIJIMA et al., 2020). However, despite condensed tannins are anti-nutritional and their low content is an advantage, they are antioxidants, denoting that their contents in the grains are important for human health.

The condensed tannins contents found for the cowpea cultivars were higher than those found by Cunha et al. (2020), who evaluated grains of two cowpea lines and found contents of 43.64 mg EC 100 g^{-1} for MNC03-737F-5-9 and 51.83 mg EC 100 g^{-1} for MNC03-737F- 5-4.

Phytic acid is found mainly in the husk of most cereals and legumes, in concentrations from 1% to 3% of the dry matter. It is found in beans, lentils, peas, textured soy protein, seeds, nuts, and whole grains. It complexes other nutrients, mainly minerals, making them unavailable. During cooking, phytate loses phosphate bonds, transforming from an inositol hexaphosphate into penta-, tetra-, or triphosphate, losing its inhibitory capacity (HIGASHIJIMA et al., 2020).

The grains of the cowpea cultivars showed significant phytic acid contents, in higher concentrations in the BRS Aracê (10.16 mg g^{-1}) and BRS Xiquexique (9.87 mg g^{-1}) and in lower concentrations in the BRS Inhuma (Table 3). A study on cowpea cultivars carried out in Colombia by De-Paula, Jarma-Arroyo and Aramendiz-Tatis (2018) showed that the cultivar Criollo Córdoba had the highest phytic acid contents (12.267 mg g^{-1}) and the cultivar L042 had the lowest content (9.63 mg g^{-1}), with better nutritional characteristics. Gonçalves et al. (2020), evaluated 18 cowpea cultivars and found a variation in phytic acid contents of 6.67 to 12.22 mg g^{-1}.

The cultivar BRS Inhuma presented lower grain condensed tannins and phytic acid contents (Table 3). These low contents of antinutritional factors indicates that this cultivar may have a greater bioavailability of minerals than the cultivars BRS Aracê and BRS Xiquexique.

Cooking quality

Cooking quality was evaluated through the percentage of cooked grains (Table 4). The cultivars showed significant differences ($p<0.05$) from each other for this characteristic; BRS Aracê was superior to the others, with the highest percentage of cooked grains (95.80%).

Table 4. Percentage of cooked grains of three cowpea cultivars.

Cultivar	Percentage of cooked grains (%)
BRS Aracê	95.80a±4.21
BRS Inhuma	42.82c±2.83
BRS Xiquexique	89.33b±3.76
Overall mean	75.98

Means±standard deviation; n=3; means followed by the same letter in the rows are not statistically different from each other by the Tukey's test ($p<0.05$).

The cultivar BRS Xiquexique showed high cooking quality (89.33%) than BRS Inhuma, which showed the lowest percentage of cooked grains (42.82%), denoting lower cooking quality than the other cultivars evaluated.

The percentage of cooked grains ranged from 42.82% to 95.80%, with a overall mean of 75.98% (Table 4). Carvalho et al. (2017) evaluated 252 common bean progenies in three locations in Minas Gerais, Brazil, using the same methodology, and found a mean percentage of cooked beans of 36.71%, well below that found in the present study. Freitas et al. (2022) evaluated 100 cowpea genotypes and found a mean percentage of cooked grains of 68.7%, which is below that found in the present work; they found percentage of cooked grains of 42% for the cultivar BRS Inhuma, which is a similar mean to that found in the present work (42.82%).

According to Freitas et al. (2022), this methodology uses a fixed mean cooking time of 30 minutes; thus, genotypes that have a high percentage of cooked beans probably reach cooking in less than 30 minutes. The cultivars BRS Aracê and BRS Xiquexique present fast cooking of grains and, therefore, they have the potential to be a highly nutritious food with less preparation time and energy consumption.

CONCLUSIONS

The cowpea cultivars BRS Aracê, BRS Inhuma, and BRS Xiquexique are good sources of macrominerals; BRS Aracê and BRS Xiquexique stand out by their high iron and zinc contents and cooking quality; and BRS Inhuma and BRS Xiquexique are rich in soluble and insoluble fibers and selenium. The cultivar BRS Inhuma has a higher content of carbohydrates and soluble dietary fiber, and lower contents of the anti-nutritional factors condensed tannins and phytic acid, compared to the cultivars BRS Aracê and BRS Xiquexique.

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