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Physical properties of grains of cowpea genotypes[1]

Propriedades físicas de grãos de genótipos de feijão-caupi

Liliane S. da Silva[2*], Abner J. de Carvalho[2], Wagner da C. Siqueira[3], Maurisrael de M. Rocha[4], Janaina B. Borges[2], Edmilson da S. Barbosa[2] & José A. E. Barbosa[2]

[1] Research developed at Instituto Federal do Norte de Minas Gerais, Laboratório de Armazenamento e Beneficiamento de Grãos e Sementes, Januária, MG, Brazil
[2] Universidade Estadual de Montes Claros, Janaúba, MG, Brazil
[3] Instituto Federal do Norte de Minas Gerais, Januária, MG, Brazil
[4] Embrapa Meio-Norte, Teresina, PI, Brazil

HIGHLIGHTS:
There is variability concerning the physical properties of cowpea genotypes.
This study describes the main physical properties of grains of 11 commercial cultivars and 17 elite lines of cowpea.
The physical properties of grains can interfere with the drying and storage process.

ABSTRACT: The present study aimed to evaluate the physical properties of cowpea genotypes grains. The study was conducted at the Laboratory for Storage and Processing of Grains and Seeds at the North Federal Institute of Minas Gerais (IFNMG) in Januária, MG, Brazil. The treatments were composed of 17 elite lines and 11 cultivars of cowpea. The experimental design was in randomized blocks with four replicates. The properties evaluated were bulk density, angle of repose, 1000-grain weight, shape (sphericity and circularity), size (projected area) of the grains, water content, and porosity of the grain mass. The genotypes give different sizes to cowpea beans, which influences the variation of bulk density, angle of repose, and 1000-grain weight. There was no statistical difference among the cowpea genotypes evaluated for water content and mass porosity.

Key words: *Vigna unguiculata* (Walp) L., grain quality, physical characteristics, post-harvest

RESUMO: Objetivou-se avaliar propriedades físicas de grãos de genótipos de feijão-caupi. O estudo foi conduzido no Laboratório de Armazenamento e Beneficiamento de Grãos e Sementes no Instituto Federal do Norte de Minas Gerais, em Januária, MG. Os tratamentos utilizados foram 17 linhagens-elite e 11 cultivares de grãos de feijão-caupi. O delineamento experimental foi em blocos casualizados, com quatro repetições. As características avaliadas foram a densidade aparente, ângulo de repouso, massa de 1.000 grãos, forma (esfericidade e circularidade), tamanho (área projetada) dos grãos, teor de água e porosidade da massa de grãos. Os genótipos conferem diferentes tamanhos aos grãos de feijão-caupi, o que influencia na variação da densidade aparente, ângulo de repouso e massa de mil grãos. Não houve diferença estatística entre as médias para as variáveis teor de água e porosidade da massa, entre os genótipos avaliados.

Palavras-chave: *Vigna unguiculata* (Walp) L., qualidade do grão, características físicas, pós-colheita

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* Corresponding author - E-mail: lilissagro@gmail.com
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Introduction

Cowpea [*Vigna unguiculata* (L.) Walp] is a legume traditionally cultivated in the North and Northeast regions of Brazil, with high socioeconomic and nutritional importance (Oba et al., 2019; Silva et al., 2020; Melo et al., 2022). According to data from the CONAB (National Supply Company), the estimated total production for the 2021/2022 harvest of the bean crop is 3,060.1 thousand tons of grains, with cowpea responsible for 720.2 thousand tons of grains, which represents 23.53% of the total production of beans in Brazil (CONAB, 2022).

Knowledge of the physical properties of grains is extremely relevant in the post-harvest stage, as grains harvested on a large scale undergo drying and cleaning steps to ensure grain quality during storage (Smirdele et al., 2017). In addition, the data obtained in this process are used in projects or adaptations of structures and equipment used, such as silos, drying, cleaning, classification, and aeration (Goneli et al., 2016). Already, there is research on several crops, such as soybean (Lopes et al., 2019), beans-cowpea (Oba et al., 2019), sunflower (Rodrigues et al., 2020), coffee (Jordan et al., 2020), algaroba (Cavalcante et al., 2020), corn (Azalim Júnior et al., 2022).

In the literature, no study considered the physical characterization of seventeen elite lines and eleven commercial cowpea cultivars in the same study. In addition, no study has been so comprehensive concerning the main physical properties studied in this research area. In this way, this study will facilitate the search by researchers regarding the cultivars already known, and even for these elite lines that are in the final phase before being commercially launched, there will already be prior knowledge about their physical properties. Given the above, the present study aimed to evaluate the main traits associated with the physical properties of cowpea genotypes grains.

Material and Methods

The study was conducted at the Grain and Seed Storage and Processing Laboratory at the North Federal Institute of Minas Gerais (IFNMG), Januária campus, MG, Brazil, in February 2020. Grains from 28 genotypes were used, 17 elite lines and 11 commercial cultivars. The genotypes evaluated refer to 17 elite lines, selected from a preliminary grain yield test, which is the last phase evaluated in Value for Cultivation and Use (Valor de Cultivo e Uso - VCU) trials, based on this agronomic information, can be launched as cultivars, where they are registered and can be commercialized, which in this work refers to the 11 cultivars evaluated: BRS Pajeú, BRS Maratoã, BRS Rouxinol, BRS Pujante, BRS Cauamé, BRS Guariba, BRS Novaera, BRS Itaim, BRS Tumucumaque, BRS Imponente, and BRS Xiquexique, produced at the Experimental Farm of the State University of Montes Claros (UNIMONTES), located in Janaúba, MG, Brazil (15° 47’ 50” S, 43° 18’ 31” W, 516 m), during the autumn-winter season, with harvest carried out in September 2019. After harvesting, the grains were stored in closed containers at the Unimontes Laboratory of Major Crops, Campus of Janaúba, MG, at room temperature.

The experimental design was in randomized blocks, with four replicates, with treatments composed of 17 elite lines and 11 commercial cultivars. The physical properties evaluated were bulk density, angle of repose, 1000-grain weight, shape (sphericity and circularity), size (projected area), water content, and porosity of the grain mass. Bulk density (BD) is the ratio between the mass and volume of a given amount of product, including intergranular spaces. More precisely, the bulk density (BD) corresponds to the mass of 100 L. For its determination, a mass of cowpea beans, previously weighed with a capacity of 0.5 L, was placed on top of a previously weighed cylinder. This cylinder has a metal trapdoor that, when removed, allows the grains to fall free to the bottom of the cylinder, as shown in Figure 1.

Then, the mass of this volume of grains was obtained, corresponding to the difference between the total mass (cylinder weight plus the mass of grains) and the cylinder mass, expressed in grams. Then, the specific mass was obtained through the value found for the mass of grains over the known volume of the cylinder, which corresponds to 0.23 m^3. The results, in grams, were corrected to kg m^{-3} and then converted into bulk density (kg hL^{-1}), according to Eqs. 1, 2, and 3.

$$M_g = M_{total} - M_{cylinder} \quad (1)$$

$$\rho = \frac{M_g}{0.25} \quad (2)$$

$$BD = \frac{\rho}{10} \quad (3)$$

Source: Silva et al. (2020)

Figure 1. Prototype used to determine the bulk density of cowpea grain samples

where:

M_g - grain mass, g;
M_{total} - total mass of grains and cylinder, g;
$M_{cylinder}$ - cylinder mass, g;
ρ - specific mass, kg m^{-3};
0.23 - cylinder volume, m^3; and,
BD - bulk density, kg hL^{-1}.

The slope angle or angle of repose is formed by the product flowing through a constant flow with the horizontal plane; this angle is influenced by the size, shape, particle orientation, and water content of the product (Mohsenin, 1986). For its determination, a device with a known base dimension of 8.9 cm was used, made of medium-density fiber (MDF) that has a trapdoor, which, when opened, allows the flow of grains, formation, and measurement of its slope (Figure 2).

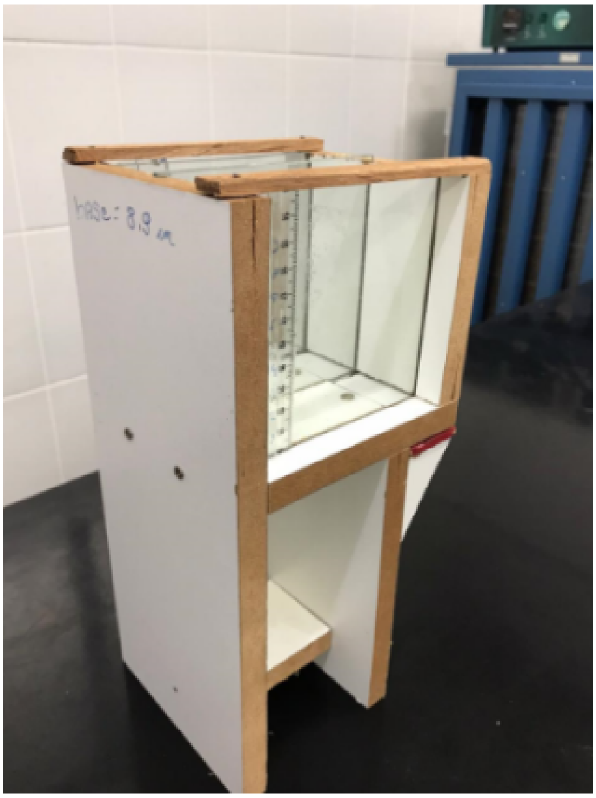
The angle formed by the grains after the flow was measured with a protractor was expressed by Eq. 4 (Mohsenin, 1986).

$$\theta = \arctan^{-1} \frac{a}{b} \tag{4}$$

where:

θ - angle of repose;
a - height; and,
b - base.

The 1000-grain weight (M1000) was obtained according to the Rules for Seed Analysis - RAS (Brasil, 2009), in which eight replicates of 100 grains were weighed on a precision scale (0.001 g), whose mean values were adjusted for the1000-grain weight and the results expressed in g, on a wet basis.



Source: Silva et al. (2020)

Figure 2. Prototype used to determine the angle of repose

The shape (sphericity and circularity) and size (projected area) of the grains were obtained according to the methodology described by Resende et al. (2005), from measurements, in fifteen grains of each sample of the characteristic dimensions, orthogonal axes (Figure 3), using a digital caliper with a precision of 0.01 mm.

The sphericity of cowpea grains was determined according to Eq. 5, described by Mohsenin (1986), represented in Figure 3:

$$E_s = \left[\frac{(a \cdot b \cdot c)^{1/3}}{a}\right] \cdot 100 \tag{5}$$

where:

Es - sphericity;
a - major grain axis, mm;
b - medium grain axis, mm; and,
c - smallest grain axis; mm.

The circularity of the grains was determined by Eq. 6, according to Mohsenin (1986):

$$C_r = \frac{d_i}{d_c} \cdot 100 \tag{6}$$

where:

C_r - circularity, %;
d_i - diameter of the largest inscribed circle, mm; and,
d_c - diameter of the smallest circumscribed circle, mm.

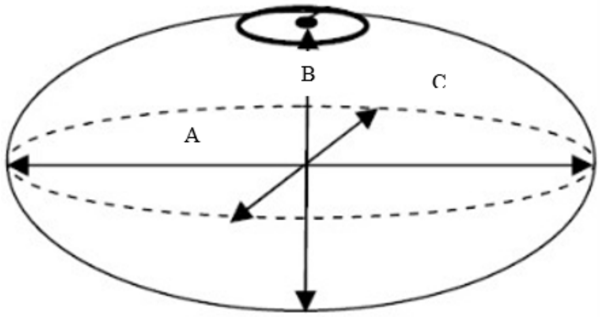
The projected area (Ap) of the grains was determined by Eq. 7 (Goneli et al., 2011).

$$Ap = \frac{\pi \cdot a \cdot b}{4} \tag{7}$$

where:

A_p - projected area, mm^2;
a - major grain axis, mm; and,
b - medium grain axis, mm.

The water content of the grains was obtained by the standard oven method, according to the Rules for Seed Analysis - RAS



Source: Resende et al. (2005)

Figure 3. Schematic drawing of the cowpea grain considered spheroid, with its characteristic dimensions, where the A axis corresponds to the largest grain axis, B the average grain axis, and C the smallest grain axis

(Brasil, 2009). For its determination, 50 g of grains from each plot were weighed, with two replicates. Then, they were placed in a crucible with known weight and taken to an oven at 130 ± 3 °C for four hours. The grain moisture was obtained from the weight difference before and after drying, expressed in %.

Two graduated cylinders of 30 mL were used to determine the porosity, with a precision of 1 mL. The first beaker was filled with free-falling grains until the grain mass filled 30 mL. The second beaker was filled with 30 mL of vegetable oil, which was poured into the first beaker until it filled all the empty spaces in the grain mass, reaching the mark of 30 mL. Then, the amount of oil needed to fill the known volume was measured, which was considered porosity, expressed in %, and estimated by Eq. 8.

$$P = \left[\frac{\left(V_{beaker\ 2} - V_{used\ 1} \right)}{V_{beaker\ 2}} \right] \cdot 100 \quad (8)$$

where:

P - porosity, in %;

$V_{beaker2}$ - fluid liquid volume; and,

$V_{used\ 1}$ - volume used to fill 30 mL of beans.

The data obtained were submitted for analysis of variance. In the case of significance, the effects of genotypes were studied using the Scott-Knott test at p ≤ 0.05.

Results and Discussion

The bulk density of the grains ranged from 74.08 to 81.39 kg hL^{-1}. The average test used separated the genotypes into two groups, the first being those that obtained the highest values (from 78.43 to 81.39 kg hL^{-1}), formed by the lines MNC11 - 1031E-5, MNC11 - 1013E-15, and MNC11 - 1052E-3 and by the cultivars BRS Tumucumaque, BRS Imponente, and BRS Xiquexique (Table 1).

The bulk density represents the weight obtained for each 100 L or 0.1 m^3 of grain. In this way, it is an important property to be considered when estimating the static capacity of silos, the capacity of the transport system, and seed classifiers according to the product to be stored (Goneli et al., 2011). The bulk density values found in this study agree with those verified by Oba et al. (2019), who studied the physical characteristics of cowpea grains in Dourados, MS, Brazil, and found values from 74.76 to 88.06 kg hL^{-1}. Davies & Zibokere (2011) found values between 64.35 and 70.66 kg hL^{-1} for cowpea cultivars. These differences show the importance of correctly determining the bulk density of the grains of each genotype for the correct sizing and/or adaptation in post-harvest and storage equipment.

The angle of repose varied between 36.55 and 57.48° (Table 1). The angle of repose is influenced by the shape and size of the grains. The cultivars BRS Tumucumaque, BRS Imponente, BRS Itaim, BRS Novaera, BRS Guariba, and the elite lines MNC11 - 1013E-33 and MNC11 - 1019E-46 showed a lower angle of repose (Table 1). Only the elite line MNC11 - 1018E-17 had the highest angle of repose concerning the previous cultivars (Table 1). The genotypes can give different sizes to the beans, which can be a factor that determines the variation of the values found (Silveira et al., 2019). Ogunngbo et al. (2018) studied Nigerian cowpea cultivars and found values ranging from 23.69 to 38.01°. Silveira et al. (2019) found an angle of repose between 27.67 and 40.67° for fava bean grains, with the samples without the drying process having the highest angles (32 and 40.67°) and the dry beans the smallest angles of repose (27.67 to 28.33°). The cowpea grains in this experiment were evaluated without any drying process, which may have contributed to higher values of the angle of repose. The methodology used must be considered, as it will influence the results.

Table 1. Clustering test of means for bulk density (BD), angle of repose (AR), 1000-grain weight (1000W), water content (WC), and porosity (POR) of the grain mass of 28 cowpea genotypes cultivated in the 2009 autumn-winter harvest, in Janaúba, MG, Brazil

Genotypes	BD (kg hL^{-1})	AR (°)	1000W (g)	WC (%)	POR
BRS Tumucumaque	81.39 a	36.55 d	276.87 b	7.00 a	71.66 a
MNC11 - 1031E-5	81.30 a	45.52 b	207.50 b	7.00 a	63.33 a
MNC11 - 1013E-15	79.65 a	48.18 b	212.50 b	8.00 a	68.33 a
MNC11 - 1052E-3	79.04 a	46.52 b	218.12 b	7.00 a	66.66 a
BRS Imponente	78.69 a	38.87 d	376.25 a	10.00 a	61.66 a
BRS Xiquexique	78.43 a	45.85 b	191.25 b	7.00 a	70.00 a
MNC11 - 1034E-2	77.73 b	49.17 b	199.37 b	7.00 a	63.33 a
BRS Rouxinol	77.39 b	44.53 b	238.12 b	8.00 a	63.33 a
BRS Itaim	77.30 b	37.87 d	276.87 b	8.00 a	68.33 a
MNC11 - 1013E-16	77.30 b	48.51 b	203.75 b	7.00 a	66.67 a
MNC11 - 1018E-17	77.21 b	57.48 a	211.87 b	6.00 a	65.00 a
MNC11 - 1013E-33	77.21 b	38.21 d	203.75 b	6.00 a	56.67 a
BRS Pajeú	77.13 b	49.54 b	218.12 b	7.00 a	63.33 a
MNC11 - 1026E-19	77.04 b	47.88 b	207.50 b	7.00 a	65.00 a
MNC11 - 1019E-12	76.95 b	51.17 b	194.37 b	5.00 a	70.00 a
BRS Novaera	76.69 b	38.21 d	196.25 b	7.00 a	68.33 a
MNC11 - 1026E-15	76.61 b	47.88 b	189.37 b	8.00 a	68.33 a
BRS Pujante	76.52 b	49.84 b	213.75 b	8.00 a	65.00 a
MNC11 - 1031E-11	76.43 b	48.21 b	199.37 b	7.00 a	70.00 a
MNC11 - 1020E-66	76.17 b	43.19 c	207.50 b	8.00 a	65.00 a
MNC11 - 1013E-35	75.91 b	42.53 c	212.50 b	7.00 a	63.33 a
BRS Guariba	75.65 b	40.20 d	196.25 b	8.00 a	73.33 a
BRS Cauamé	75.56 b	47.18 b	213.75 b	8.00 a	66.67 a
MNC11 - 1019E-8	75.39 b	48.18 b	211.87 b	16.00 a	66.67 a
BRS Maratoã	75.22 b	46.88 b	238.12 b	8.00 a	63.33 a
MNC11 - 1019E-46	75.21 b	38.87 d	194.37 b	7.00 a	65.00 a
MNC11 - 1022E-58	74.17 b	45.19 b	207.50 b	9.00 a	66.67 a
MNC11 - 1013E-15	74.08 b	42.86 c	189.37 b	6.00 a	68.33 a
CV (%)	3.49	6.85	19.02	31.67	4.04

Means followed by the same letter in the column belong to the same cluster by the Scott-Knott test at p ≤ 0.05; CV - Coefficient of variation

There was a significant difference for the variable 1000-grain weight (1000W), and there was no significant difference for the variables water content (WC) and porosity of grain mass (POR) between the evaluated genotypes (Table 1). The cultivar BRS Imponente presented the highest value of 1000-grain weight, 376.25 g, and a smaller angle of repose, 38.87° (Table 1), that can be related to the projected area of the grain (Table 2). The 1000-grain weight directly influences the number of seeds used per hectare, and its variation may be due to the size of the seed and the genotype (Peixoto, 1999). The 1000-grain mass ranged from 189.37 to 376.25 g. Hamid et al. (2016) found a 1000-grain weight of 130.78 g for cowpea varieties in the color group. Davies & Zibokere (2011), studying the physical properties of Nigerian cowpea genotypes, found 1000-grain weights ranging from 253.8 to 279.12 g for grains. Determining the 1000-grain weight is essential, as it gives an idea of the size of the seeds and indicates the space they occupy in a given volume, which will be used for calculations of storage in silos, calculation of packaging costs, transport, and for calculating the number of seeds needed to plant a given area.

There was no significant difference between the means for the variable grain water content (Table 1). Although the genotypes studied did not show the statistical difference, the water content influences the size of the grains, whereas, in a study done with peanuts, it was concluded that, for reduction of the water content, there was a decrease in the projected area (Araújo et al., 2014). Thus, it is important to know the physical characteristic of each genotype due to the genetic variability found in this study or other physical properties studied, such as bulk density, angle of repose, 1000-grain weight, and grain shape and size. In addition, the water content of the grain is a determining factor for the maintenance of grain or seed quality during the harvest, post-harvest, and storage phases, and its knowledge is of fundamental importance (Ullmann et al., 2015).

There was no statistical difference between the means for the porosity of the grain mass variable (Table 1). The porosity of the grain mass can be understood as the space created between the grains of a certain cultivar in a state of rest and is directly linked to the efficiency in the use of machines, equipment, and structures during the harvesting, post-harvesting, and storage phases (Quequeto et al., 2018). Oba et al. (2019) observed that the porosity of the mass of cowpea beans from the BRS Guariba cultivar in Dourados, MS, Brazil, was 41.8%. The porosity of the grain mass in this study was determined with grain without a drying process, with humidity around 12%, different from the studies mentioned above, which evaluated the physical properties of the grains after drying in an oven. According to Quequeto et al. (2018), with the decrease in moisture content, the grains tend to present volumetric contraction, reducing empty spaces between grains. For these same authors, information regarding the volumetric contraction of the mass can be used in calculating the volume of the grains to be replaced in the drying chamber of the dryer, thus working efficiently and optimizing its use.

Determining the porosity of the grains is very important, as the smaller or larger intergranular voids may indicate greater or lesser resistance offered to the passage of air through the mass of the product, affecting the behavior, uniformity, and efficiency of the drying or aeration operations (Li et al., 2019).

The sphericity of the grains ranged from 68.49 to 79.23% among the evaluated genotypes, which were divided into three groups (Table 2). Higher sphericity values indicate a more spherical shape of the grains, which will certainly interfere with other physical properties of the grains, such as the angle of repose and, consequently, in operations related to harvest, post-harvest, and grain storage (Gomes et al., 2018).

Oba et al. (2019) found mean values of 73.9% for the sphericity of cowpea grains for cultivar BRS Guariba. Hamid et al. (2016) found mean values of 87.64% for cowpea beans from the color group in India. Davies & Zibokere (2011) reported sphericity ranging from 67 to 79% for several cowpea cultivars in Nigeria.

Grain circularity ranged from 65.44 to 78.44% (Table 2). The lines MNC11-1052E-3, MNC11-1019E-46, and MNC11-1016E-16, and the cultivars BRS Rouxinol, BRS Maratoã, and BRS Pajeú obtained the highest values, with grain circularity ranging from 75.38 to 78.44%. Mohsenin (1986) considered that, for agricultural products such as seeds and fruits to be considered circular, they must have circularity magnitudes above 90%. Thus, in this study, it is impossible to classify the cowpea grains as circular.

Gomes et al. (2018), studying the grain circularity of the cultivars BRS Novaera and BRS Tumucumaque, found mean values of 73.19 and 70.78%, respectively, in Rio Verde, GO, Brazil. These values corroborate those found for these same cultivars in the current study, which showed a circularity of 74.63% for BRS Novaera and 70.03% for BRS Tumucumaque.

The circularity of plant products can be used to determine the lower limit of the size of conveyors such as belts, bucket elevators, and screw conveyors (Araújo et al., 2014). In a practical sense, this information determines the shape and size of sieve holes used to process seeds and grains.

The projected area of the grains ranged from 42.45 to 84.21 mm². BRS Imponente obtained the largest projected area, 84.21 mm². This value was already expected, as it is due to the genetic characteristics of this cultivar, highlighting the rough integument of extra large size, with an average weight of 34 g for every 100 grains. Thus, the greater the value of this dimension, the greater the projected area. The BRS Novaera

Table 2. Clustering test for shape (sphericity - SPH and circularity - CIR) and size (projected area - AREA) of grains of 28 cowpea genotypes cultivated in the 2019 autumn-winter harvest, in Janaúba, MG, Brazil

Genotypes	SPH	CIR	AREA
	(%)		(mm²)
MNC11-1052E-3	79.23 a	78.44 a	52.46 d
MNC11-1013E-33	79.23 a	73.51 b	46.84 e
BRS Maratoã	78.56 a	76.44 a	45.41 f
MNC11-1016E-16	77.37 a	76.55 a	44.72 f
BRS Pujante	76.92 a	73.57 b	43.58 f
BRS Pajeú	76.77 a	75.38 a	45.78 e
MNC11-1019E-12	76.52 a	74.85 b	46.95 e
MNC11-1019E-46	76.45 a	77.29 a	51.24 d
MNC11-1018E-17	75.97 a	74.64 b	53.08 d
MNC11-1031E-11	75.97 a	73.37 b	47.50 e
MNC11-1026E-15	75.87 a	74.06 b	45.99 e
BRS Rouxinol	75.81 a	76.80 a	47.13 e
MNC11-1022E-58	75.75 a	74.46 b	47.39 e
MNC11-1019E-8	75.33 a	72.92 b	49.82 d
MNC11-1031E-5	75.30 a	72.85 b	49.74 d
MNC11-1026E-19	75.11 a	72.59 b	46.67 e
MNC11-1024E-1	74.87 a	73.08 b	52.03 d
MNC11-1013E-35	74.79 a	72.83 b	51.12 d
BRS Novaera	74.56 a	74.63 b	59.68 b
MNC11-1034E-2	74.03 b	71.85 b	52.78 d
BRS Xiquexique	73.83 b	73.41 b	44.63 f
BRS Cauamé	73.59 b	72.39 b	42.45 f
MNC11-1013E-15	73.24 b	70.36 c	55.24 c
BRS Guariba	73.01 b	69.49 c	48.81 e
MNC11-1013E-16	72.81 b	68.77 c	48.18 e
BRS Tumucumaque	71.55 c	70.03 c	44.03 f
BRS Imponente	70.51 c	69.92 c	84.21 a
BRS Itaim	68.49 c	65.44 d	53.00 d
CV%	2.02	2.02	2.91

Averages followed by the same letter in the column belong to the same group by the Scott-Knott test at p ≤ 0.05; CV - Coefficient of variation obtained the second highest value for the projected area, with 59.68 mm^2, followed by the line MNC11-1013E-15, which obtained a projected area of 55.24 mm^2. Gomes et al. (2018) found values of 66.82 and 56.15 mm^2 for the cultivars BRS Novaera and BRS Tumucumaque, respectively.

Knowledge about shape (sphericity and circularity) and size (projected area) are still scarce for cowpea. Araújo et al. (2014) carried out a study for the grains of cowpea cultivar BRS Novaera, where they were classified by width (medium axis), using sieves number 17, 18, 19, and 20 with sieve diameters of 6.74; 7.14; 7.54, and 7.94 mm, respectively. However, studies with this theme are found more for the common bean (*Phaseolus vulgaris*). Thus, studies of this magnitude for the cowpea crop are essential, and further information can be obtained through the shape and size of the grains, such as resistance to the passage of air through the mass of the product, heat dissipation on its surface, assistance in heat and mass transfer studies and in the design of equipment for drying agricultural products.

Conclusions

1. The genotypes give different sizes to cowpea beans, which influences the variation of bulk density, angle of repose, and 1000-grain weight.

2. There was no statistical difference among the cowpea genotypes for water content and porosity of grain mass.

Literature Cited

Araújo, W. D.; Goneli, A. L. D.; Souza, C. M. A. de; Gonçalves, A. A.; Vilhasanti, H. C. B. Propriedades físicas dos grãos de amendoim durante a secagem. Revista Brasileira de Engenharia Agrícola e Ambiental, v.18, p.279-286, 2014. https://doi.org/10.1590/S1415-43662014000300006

Azalim Júnior, F. A.; Tolentino, E. L.; Souza, J. L. F. de; Costa, L. A. da; Ferreira, A. G.; Dias, A. A. Validação do modelo matemático de secagem de grãos de milho em leito fixo utilizando CFD. Brazilian Journal of Development, v.8, p.48209-48227, 2022. https://doi.org/10.34117/bjdv8n6-362

Brasil. Ministério da Agricultura e Reforma Agrária. Regras para Análise de Sementes. Brasília: MAPA, 2009. 399p.

Cavalcante, A. M. de M.; Almeida, R. D.; Melo, A. M. de; Morais, B. A. de; Silva, I. R. da; Ribeiro, N. L.; Alexandre, H. V.; Silva, O. S. da. Modelos de predição da cinética de secagem dos grãos da algaroba. Revista Brasileira de Desenvolvimento, v.6, p.11192-11209, 2020 https://doi.org/10.34117/bjdv6n3-113

CONAB - Companhia Nacional de Abastecimento. Monitoramento da safra brasileira de grãos: 2021/22 colheita. Available on: <https://www.conab.gov.br/info-agro/safras/graos>. Accessed on: Fev 2022.

Davies, R. M.; Zibokere, D. S. Effects of moisture content on some physical and mechanical properties of three varieties of cowpea (*Vigna unguiculata* (L) walp). Agricultural Engineering International: CIGR Journal, v.13, p.1-8, 2011. http://www.cigrjournal.org/index.php/Ejounral/ article/view/1700/1441

Gomes, F. H. F.; Lopes Filho, L. C.; Oliveira, D. E. C. de; Resende, O.; Soares, F. A. L. Tamanho e forma de grãos de feijão-caupi em função de diferentes teores de água. Revista Engenharia na Agricultura, v.26, p.407-416, 2018. https://doi.org/10.13083/reveng.v26i5.957

Goneli, A. L. D.; Corrêa, P. C.; Magalhães, F. E. de A.; Baptestini, F. M. Contração volumétrica e forma dos frutos de mamona durante a secagem. Acta Scientiarum. Agronomy, v.33, p.1-8, 2011. https://doi.org/10.4025/actasciagron.v33i1.4629

Goneli, A. L. D.; Martins, E. A. S.; Jordan, R. A.; Geisenhoff, L. O.; Garcia, R. T. Experimental dryer design for agricultural products. Engenharia Agrícola, v.36, p.938-950, 2016. https://doi.org/10.1590/1809-4430-Eng.Agric.v36n5p938-950/2016

Hamid, S.; Muzaffar, S.; Wani, I. A.; Masoodi, F. A.; Bhat, M. M. Physical and cooking characteristics of two cowpea cultivars grown in temperate Indian climate. Journal of the Saudi Society of Agricultural Sciences, v.15, p.127-134, 2016. http://dx.doi.org/10.1016/j.jssas.2014.08.002

Jordan, R. A.; Siqueira, V. C.; Cavalcanti-Mata, M. E. R. M.; Hoscher, R. H.; Mabasso, G. A.; Motomiya, A. V. de A.; Oliveira, F. C de; Martins, E. A. S.; Santos, R. C.; Quequeto, W. D. Drying kinetics of natural and parchment coffee at low temperature and relative humidity using a heat pump. Research, Society and Development, v.9, p.1-20, 2020. https://doi.org/10.33448/rsd-v9i8.5528

Li, T.; Li, C.; Ti, C; Xu, F.; Fang, Z. Porosity of flowing rice layer: experiments and numerical simulation. Biosystems engineering, v.179, p.1-12, 2019. https://doi.org/10.1016/j.biosystemseng.2018.12.003

Lopes, M. A.; Resende, O.; Bessa, J.; Lima, R.; Quequeto, W. D. Propriedades físicas dos grãos de soja, cotilédones e impurezas. Revista de Ciências Agrárias, v.42, p.962-970, 2019. https://doi.org/10.19084/rca.18030

Melo, A. S. de; Melo, Y. L.; Lacerda, C. F. de; Viégas, P. R. A.; Ferraz, R. L. de S.; Gheyi, H. R. Water restriction in cowpea plants [*Vigna unguiculata* (L.) Walp.]: Metabolic changes and tolerance induction. Revista Brasileira de Engenharia Agrícola e Ambiental, v.26, p.190-197, 2022. https://doi.org/10.1590/1807-1929/agriambi.v26n3p190-197

Mohsenin, N. N. Physical properties of plant and animal materials. New York: Gordon and Breach Publishers, 1986. 841p.

Oba, G. C.; Goneli, A. L. D.; Martins, E. A. S.; Hartmann Filho, C. P.; Gonçalves, A. A. Caracterização física das sementes de feijão-caupi, cultivar brs guariba, durante o processo de secagem. Energia na Agricultura, v.34, p.283-296, 2019. https://doi.org/10.17224/EnergAgric.2019v34n2p283-296

Ogunngbo, O. C.; Adetan, D.; Olusola, O. F. Effect of soaking time on some engineering properties of cowpea (*Vigna unguiculata*). Agricultural Engineering International: CIGR Journal, v.20, p.143-149, 2018. https://cigrjournal.org/index.php/Ejounral/article/view/4052

Peixoto, C. P. Análise de crescimento e rendimento de três cultivares de soja em três épocas de semeadura e três densidades de plantas. Universidade de São Paulo, Piracicaba, 1999. Tese Doutorado

Quequeto, W. D.; Siqueira, V. C.; Schoeninger, V.; Martins, E. A. S.; Isquierdo, E. P.; Silva, F. P. da. Physical properties of buckwheat (*Fagopyrum esculentum* Moench) grains during convective drying. Revista brasileira de Engenharia Agrícola e Ambiental, v.22, p.793-798, 2018. https://doi.org/10.1590/1807-1929/agriambi.v22n11p793-798

Resende, O.; Corrêa, P. C.; Goneli, A. L. D.; Cecon, P. R. Forma, tamanho e contração volumétrica do feijão (*Phaseolus vulgaris* L.) durante a secagem. Revista Brasileira de Produtos Agroindústriais, v.7, p.15-24, 2005. http://dx.doi.org/10.15871/1517-8595/rbpa.v7n1p15-24

Rodrigues, L. M. de S.; Ferreira, J. S.; Gomes, J. P.; Silva, S. do N.; Vieira, A. F.; Silva, L. P. F. R. da; Silva, A. de O.; Pereira, M. S. Influência do tempo de secagem nas propriedades físicas de *Helianthus annuus*. Brazilian Journal of Development, v.6, p.81553-81559, 2020. https://doi.org/10.34117/bjdv6n10-544

Silva, A. L. da; Batista, P. S. C.; Oliveira, K. J. O. de; Cruz, C. A. da; Cangussú, L. V. S. de; Santiago, W. E. Desempenho Agronômico de feijão-caupi de porte semiereto e semiprostado em diferentes populações. Revista Brasileira de Agropecuária Sustentável, v.10, p.193-198. 2020. https://doi.org/10.21206/rbas.v10i1.9636

Silveira, D. C. da; Leite, A. C. N.; Santos, N. C.; Gomes, J. P. Physical characteristics of broad bean beans (*Phaseolus lunatus* L.). Revista Verde de Agroecologia e Desenvolvimento Sustentável, v.14, p.518-523. 2019. https://doi.org/10.18378/rvads.v14i4.6811

Smirdele, O. J.; Souza, A. G.; Alves, J. M. A.; Barbosa, C. Z. R. Physiological quality of cowpea seeds for different periods of storage. Revista Ciência Agronômica, v.48, p.817-823, 2017. https://doi.org/10.5935/1806-6690.20170096

Ullmann, R.; Resende, O.; Chaves, T. H.; Oliveira, D. E. C. de; Costa, L. M. Qualidade fisiológica das sementes de sorgo sacarino submetidas à secagem em diferentes condições de ar. Revista Brasileira de Engenharia Agrícola e Ambiental, v.19, p.64-69. 2015. https://doi.org/10.1590/1807-1929/agriambi.v19n1p64-69