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Processing on the physical and physiological quality of chickpea (*Cicer arietinum* L.) seeds

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ABSTRACT: Processing consists of sequential operations aimed at cleaning, classifying, and treating seeds, with the goal of improving the quality of the lot. The aim of this study was to evaluate the effect of the processing stages on the physical and physiological quality of chickpea seeds, cultivar BRS Cícero. Seeds were sampled before processing and after passing through the air screen machine (upper sieve of 12 mm and lower sieve of 7.5 mm), elevators, storage silo, and gravity table (upper discharge, high intermediate, low intermediate, and lower discharge). The seeds were evaluated for moisture content, physical purity, germination test, electrical conductivity test, emergence in sand, emergence speed index, accelerated aging, and tetrazolium test. The processing resulted in increased physical purity and reduced percentage of broken seeds in the lot of chickpea seeds. Seeds collected from the upper and intermediate chutes of the gravity table showed higher germination values. Seed processing using the air screen machine and the gravity table is effective in improving the physical and physiological quality of the lot of chickpea seeds, cultivar BRS Cícero.

Index terms: gravity table, pulses, vegetables.

RESUMO: O beneficiamento consiste em operações sequenciais que visam limpar, classificar e tratar as sementes, visando a melhoria da qualidade do lote. Objetivou-se com este trabalho avaliar o efeito das etapas de beneficiamento na qualidade física e fisiológica de sementes de grão-de-bico, cultivar BRS Cícero. As sementes foram amostradas antes do processamento e após a saída da máquina de ventilador e peneiras (peneira superior de 12 mm e inferior de 7,5 mm), elevadores, silo armazenador e mesa de gravidade (descarga superior, intermediária alta, intermediária baixa e inferior). As sementes foram avaliadas quanto aos teores de água, pureza física, teste de germinação, teste de condutividade elétrica, emergência em areia, índice de velocidade de emergência, envelhecimento acelerado e teste de tetrazólio. O beneficiamento promoveu o aumento da pureza física e redução do percentual de sementes quebradas no lote de sementes de grão-de-bico. As sementes coletadas nas bicas superiores e intermediárias da mesa de gravidade apresentaram valores superiores de germinação. O beneficiamento de sementes, utilizando a máquina de ar e peneiras e a mesa de gravidade, é eficiente para o aprimoramento da qualidade física e fisiológica do lote de sementes de grão-de-bico cultivar BRS Cícero.

Termos para indexação: mesa de gravidade, pulses, hortaliças.

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INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a Fabaceae species of great importance, being the third most consumed in the world and constituting around 20% of the world production of legumes (Ullah et al., 2020). In addition to being an excellent source of protein, chickpeas are rich in carbohydrates, minerals, vitamins, and fiber, differentiating themselves from other legumes by their higher digestibility and low content of antinutritional substances (Merga and Haji, 2019).

Brazil has only eight chickpea cultivars registered in the National Register of Cultivars (*Registro Nacional de Cultivares* - RNC), namely: Amâ, Apu, BRS Cícero, BRS Aleppo, BRS Cristalino, BRS Toro, BRS Kalifa and IAC Marrocos (Brasil, 2022). It should be noted that there is a dimensional variability of seed size according to the cultivar; for instance, the cultivars IAC Marrocos and BRS Aleppo have medium-sized seeds, while BRS Cícero has larger seeds (Dias et al., 2019).

Processing consists of the process by which sequential operations are carried out on specific equipment, through which the seeds are cleaned, classified and treated to improve the quality of the lot. However, even with increasingly precise equipment, which reduces damage and improves the quality of the lot, it is necessary to measure the effects caused by the processing on quality.

Araújo et al. (2011) observed that the use of air screen machine and the gravity table eliminates undesirable materials, increasing the physical and sanitary purity of lots of mung bean seeds. Also, Gadotti et al. (2020) observed that coriander processing was efficient in separating seeds with better sanitary quality, by removing contaminated seeds. Similar results have been found for other crops, such as castor bean (Santos-Neto et al., 2012) and soybean (Teles et al., 2013; Juvino et al., 2014; Moreano et al., 2018; Folquini et al., 2022). Regarding chickpea, there is no information in the literature so far.

Therefore, the aim of this study was to evaluate the effect of the processing stages on the physical and physiological quality of chickpea (*Cicer arietinum* L.) seeds, cultivar BRS Cícero.

MATERIAL AND METHODS

Chickpea seeds, cultivar BRS Cícero, were mechanically harvested in a production field of Embrapa-Hortaliças, in Brasília-DF, Brazil. The seeds were harvested with 10% moisture content. Subsequently, they were processed at the Seed Processing Unit (SPU) of the same company, passing through the air screen machine and the gravity table.

After stabilizing the operation of the machines, approximately one hour after the beginning of the process, samples (seeds) were collected at each stage of the processing, with regular intervals of five minutes between samplings. Approximately 25 single samples of each treatment were collected, with an average weight of 240 g, obtained at different points depending on the machines and equipment, according to the flowchart and descriptions presented in Figure 1 and Table 1.

For each treatment, the single samples were grouped/homogenized into composite samples to form the average samples (6000 g), which were sent for analysis in the laboratory. Ten treatments were obtained in the various stages of processing and in the different machines (Table 1 and Figure 1).

In the Laboratory, the quality of the seeds of each treatment was evaluated by the following tests and evaluations:

Moisture content: performed by the oven method at 105 ± 3 °C, with four replications of 25 g of seeds each, according to Brasil (2009). The results were expressed as a percentage (%).

Physical purity: in four replications of 1,000 g, the components were separated by manual picking with the aid of tweezers. The results were expressed as percentage of pure seeds (P) and broken seeds (BS) (Brasil, 2009).

Germination: conducted with four replications of 50 seeds, using as substrate the Germitest paper, moistened with distilled water in the proportion of 2.5 times its dry weight. The paper rolls with the seeds were kept in a germination chamber at 20 °C. Evaluations were performed at 5 (first count) and 8 days, computing the seedlings considered normal, and the results were expressed in % (Brasil, 2009).

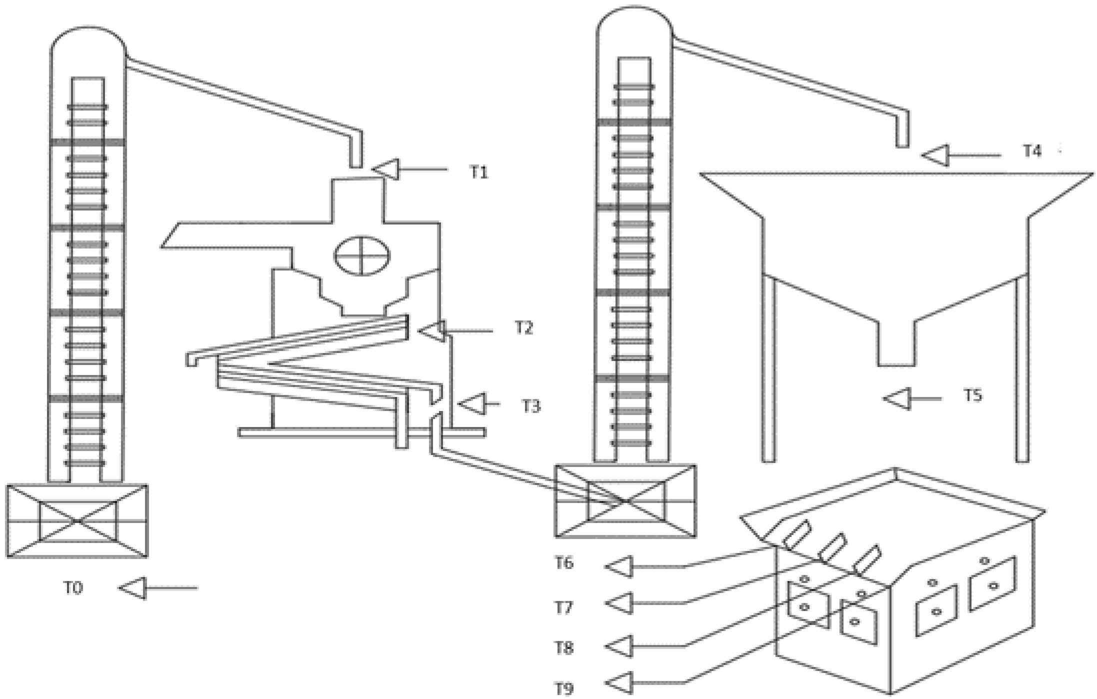

Figure 1. Flowchart of the stages of processing of chickpea seeds, indicating the points for collecting the samples to constitute the treatments (T0, T1, T2, T3, T4, T5, T6, T7, T8 and T9).

Table 1. Description of the treatments, represented by the points of collection of seed samples in the stages of chickpea processing.

TREATMENTS	DESCRIPTION
T0	Composed of the raw material (seeds + possible impurities), that is, not processed (T0).
T1	Material (seeds + possible impurities) collected after passing through the first elevator and before the air screen machine (ASM)
T2	Material (seeds + possible impurities) collected at the ASM, after passing through the 12-mm-mesh upper sieve (round holes) and before the 7.5-mm-mesh lower sieve (round holes).
T3	Material (seeds + possible impurities) collected at the ASM, which was retained on the 7.5-mm-mesh lower sieve (round holes) and before the second elevator. The purpose of this sieve is to remove extremely small seeds (< 7.5 mm in diameter).
T4	Material (seeds + possible impurities) collected after passing through the second elevator, responsible for feeding a storage silo.
T5	Material (seeds + possible impurities) collected at the outlet of the storage silo.
T6	Material (seeds + possible impurities) collected at the upper discharge of the gravity table.
T7	Material (seeds + possible impurities) collected at the high intermediate discharge of the gravity table.
T8	Material (seeds + possible impurities) collected at the low intermediate discharge of the gravity table.
T9	Material (seeds + possible impurities) collected at the lower discharge of the gravity table.

Electrical conductivity: performed with four replications of 50 intact seeds, previously weighed on a precision scale. The seeds were placed in disposable cups with capacity of 200 mL, in which 75 mL of distilled water were added. The cups with the seeds and water were placed in a germination chamber (B.O.D.) at 25 °C and kept for 24 hours. Subsequently, the electrical conductivity of the seed soaking solution was read with the conductivity meter, and the results were expressed in µS.cm^{-1}.g^{-1} (Vieira and Krzyzanowsky, 1999).

Emergence in sand: conducted in plastic trays containing sand, using 100 seeds for each treatment, divided into four replications of 25 seeds, sown at 3 cm depth. The trays were kept under ambient conditions, where irrigation was done frequently. Emergence percentage was calculated by computing the total seedlings emerged after complete stabilization of the stand (ten days after setting up the test).

Emergence speed index: calculated with the daily values obtained from the number of plants emerged, from the first to the last day of duration of the emergence test, according to Maguire (1962). Seedlings with the cotyledons above the substrate surface were considered emerged (Nakagawa, 1999).

Accelerated aging: performed with four replications of 50 seeds, for each treatment, which were arranged in a single layer and distributed on a plastic screen, fixed inside a "gerbox" plastic box, containing sodium chloride (NaCl) solution at the bottom. Then, the boxes were closed and placed in a B.O.D. chamber, at 41 °C, where they were kept for 24 hours (Dias et al., 2020). After this period, the seeds were placed to germinate according to the methodology described for the germination test, and the evaluation of the number of normal seedlings was performed at five days after setting up the test, expressing the results in percentage (%).

Tetrazolium test: performed with four replications of 25 seeds each, placed in pre-conditioning to soak in sheets of Germitest paper moistened with an amount of water equal to 2.5 times the weight of the dry paper, and kept in a germination chamber at a temperature of 30 °C for 18 hours. Subsequently, the seeds were subjected to tetrazolium solution at 0.1% concentration for 6 hours, in a germination chamber, in the dark, at a temperature of 30 °C. After this period, the solution was drained and then the seed coat was removed. Subsequently, the seeds were longitudinally sectioned through the embryo using a scalpel, and the internal and external analysis was performed, quantifying the levels of vigor and viability and identifying the causes of the loss of physiological quality of the seeds, due to mechanical damage, bugs and/or humidity (Paraíso et al., 2019).

Finally, the seeds were subjected to the classification proposed by Paraíso et al. (2019), as follows: Class 1 - viable and vigorous seeds, with absence of lesions; Class 2 - viable and vigorous seeds, with superficial lesions distant from the vital parts; Class 3 - viable and non-vigorous seeds, with lesions in the embryonic axis that did not affect the vascular cylinder; Class 4 - non-viable seeds, with damage to vital parts, compromising the normal development of the seedling.

The results were expressed as percentage of viable seeds (TZVB) (classes 1, 2 and 3), percentage of vigorous seeds (TZVG) (class 1 and 2), percentage of seeds with mechanical damage (TZMD) (class 2, 3 and 4), and percentage of seeds without damage (SWoD) (class 1) (Paraíso et al., 2019).

The experimental design was completely randomized, with ten treatments and four replications. The data were evaluated for normality and homogeneity of the residuals by the Kolmogorov-Smirnov and Layard/Samiuddin tests, respectively. Then, they were subjected to analysis of variance ($p < 0.05$) by means of the F test and, when significant, the means were compared by Tukey test ($p < 0.05$). It is worth pointing out that the TZVB variable did not show normality and, therefore, was evaluated by the Kruskal-Wallis test at 5% probability level.

RESULTS AND DISCUSSION

The analysis of variance of the data related to the evaluated characteristics is shown in Table 2, except for TZVB, which did not show normality. It can be observed that the variables moisture content, accelerated aging, seedling emergence, emergence speed index, vigor by the tetrazolium test, mechanical damage by the tetrazolium test and seeds without damage by the tetrazolium test did not show statistical difference between the treatments evaluated ($P > 0.05$). However, the other variables, such as purity, broken seeds, first germination count, germination and electrical conductivity, were influenced by the different stages of processing ($P < 0.05$).

The initial moisture content of the seeds did not differ statistically between processing stages, with a mean value of 10.1% (Table 3). This similarity of values is important so that quality tests are not affected. Marcos-Filho (2016)

Table 2. Summary of the analysis of variance (P value and coefficient of variation – CV) of the data regarding moisture content (MC), purity (P), broken seeds (BS), first germination count (FGC), germination (G), seedling emergence (E), emergence speed index (ESI), electrical conductivity (EC), accelerated aging (AA), vigor by tetrazolium test (TZVG), mechanical damage by tetrazolium test (TZMD) and seeds without damage by tetrazolium test (SWoD), according to the stages of the processing of chickpea seeds, cultivar BRS Cícero.

Factor of Variation	MC	P	BS	FGC	G	E
Processing Stages	0.0571	< 0.0001	< 0.0001	0.0013	0.04215	0.8876
CV (%)	1.39	2.32	11.68	7.04	7.8	21.82
Factor of Variation	ESI	EC	AA	TZVG	TZMD	SWoD
Processing Stages	0.0859	0.0347	0.8516	0.5607	0.1093	0.1224
CV (%)	26.11	5.99	10.03	16.78	15.54	42.97

Table 3. Moisture content (MC), purity (P), broken seeds (BS) and germination (G), according to stages of processing of chickpea seeds, cultivar BRS Cícero.

Treatment	MC**	P*	BS*	G*
	(%)	(%)	(%)	(%)
T0-raw sample	10.1 a	84.27 e	12.82 b	74.5 ab
T1-elevator 1	11.0 a	83.38 e	12.75 b	81.5 ab
T2-12 mm sieve	11.0 a	85.29 de	12.87 b	73.5 ab
T3-7.5 mm sieve	11.0 a	91.88 bc	8.07 cd	77.5 ab
T4-elevator 2	10.9 a	91.51 c	8.20 c	72.8 ab
T5-storage silo	10.9 a	89.33 cd	10.42 bc	79.0 ab
T6-upper discharge	10.8 a	96.35 ab	3.64 de	77.0 ab
T7-high intermediate discharge	10.8 a	96.84 a	3.15 e	84.0 a
T8-low intermediate discharge	10.8 a	92.13 bc	7.86 cd	79.0 ab
T9-lower discharge	11.1 a	20.93 f	78.62 a	68.5 b
Mean	10.8	-	-	-

*Means followed by the same letter in the column do not differ statistically from each other by Tukey test at 5% probability level; **Means followed by the same letter in the column do not differ statistically from each other by the F test at 5% probability level.

reports that seed moisture content directly influences several aspects of physiological quality, such as the speed of deterioration and, therefore, its determination is fundamental in official quality tests of seed lots.

In the different stages of processing, it was observed that the physical purity ranged from 20.93 to 96.84 % (Table 3). It is observed that the material collected from the lower discharge of the gravity table (T9) had the lowest purity value, while samples collected from the upper (T6) and high intermediate (T7) discharges had the highest values (96.35 and 96.84%, respectively). It is worth pointing out that, at the lower discharge of the gravity table (T9), there was a predominance of empty pods and pieces of plants, which was already expected, because these materials are lighter. The principle of use of the gravity table in seed processing is to separate the seeds of lower specific weight (lower physiological quality) and then conduct them to the lower discharge of the instrument (Moreano et al., 2013).

According to Normative Instruction No. 42 of the Ministry of Agriculture, Livestock and Food Supply (MAPA), the minimum purity standard for the marketing of certified chickpea seeds (C1 and C2) is 97% (Brasil, 2019). It can be observed that the purity of T6 and T7 is very close to 97%; however, it is recommended to make more precise adjustments in the gravity table to reach the marketing standard.

Therefore, the importance of using the air screen machine and gravity table in the processing of chickpea seeds is highlighted. Similar results have been found for seeds of soybean (Moreano et al., 2013; Teles et al., 2013) and mung beans (Araújo et al., 2011), for which the use of the air screen machine and gravity table substantially improves the final quality of the seed lots.

The percentage of broken seeds ranged from 3.15 to 78.62 % (Table 3). It is observed that the lower discharge of the gravity table (T9) had higher values of broken seeds (78.62%), which was already expected, as the material collected has lower specific weight. In addition, the T0 treatment (raw lot, without processing), had 12.82% of broken seeds, highlighting that the harvest caused mechanical damage to the seeds.

The processing of seeds reduced the percentage of broken seeds, especially after the passage of seeds in the air screen machine (T3) and gravity table (T6 and T7), with values of 8.07, 3.64 and 3.05%, respectively (Table 3).

Also in Table 3, it can be seen that germination did not show great distinction in its value during processing, with only one statistical difference, when the seeds collected at the high intermediate discharge of the gravity table (T7) had higher germination values than seeds collected at the lower discharge (T9). Similar results were found in the processing of mung bean seeds (Araujo et al., 2011). Moreano et al. (2013) verified in their study that the cleaning machine did not improve the physiological quality of soybean seeds, but this characteristic was improved after the passage of the seeds on the gravity table.

It should also be noted that seed germination ranged from 68.50 to 84.0%, in accordance with Normative Instruction No. 42 of the Ministry of Agriculture, Livestock and Food Supply (MAPA), which establishes the minimum value of 60% for the marketing of certified chickpea seeds (C1 and C2) in Brazil (Brasil, 2019). Therefore, it was observed that, in all stages of processing, the seeds had germination higher than that required by the Brazilian legislation.

The results of the first germination count, electrical conductivity, accelerated aging, emergence, emergence speed index tests are presented in Table 4. The values of the first germination count were close to those of the germination count, especially for seeds from the lower discharge of the gravity table (T9), which led to the lowest percentage of normal seedlings (68.50%). Regarding the results of electrical conductivity, its values ranged from 115.36 to 135.57

Table 4. First germination count (FGC), electrical conductivity (EC), accelerated aging (AA), emergence (E) and emergence speed index (ESI), according to stages of processing of chickpea seeds, cultivar BRS Cícero.

Treatment	FGC*	EC*	AA**	E**	ESI**
	(%)	$\mu S.cm^{-1}.g^{-1}$	(%)	(%)	
T0-raw sample	71.75 ab	115.36 b	69.50 a	56.0 a	9.5 a
T1-elevator 1	76.75 ab	122.59 ab	70.50 a	53.0 a	9.4 a
T2-12 mm sieve	68.50 b	121.72 ab	67.0 a	52.0 a	9.1 a
T3-7.5 mm sieve	75.0 ab	131.06 ab	71.0 a	53.0 a	12.2 a
T4-elevator 2	67.75 b	126.29 ab	74.50 a	62.0 a	11.8 a
T5-storage silo	79.0 ab	130.35 ab	70.0 a	56.0 a	11.4 a
T6-upper discharge	77.0 ab	130.75 ab	72.25 a	55.0 a	9.5 a
T7-high intermediate discharge	84.0 a	131.04 ab	76.0 a	58.0 a	12.2 a
T8-low intermediate discharge	78.5 ab	126.93 ab	70.0 a	58.0 a	14.6 a
T9-lower discharge	68.50 b	135.57 a	71.75 a	47.0 a	8.3 a
Mean	-	-	71.25%.	55.0%	10.8

*Means followed by the same letter in the column do not differ statistically from each other by Tukey test at 5% probability level; **Means followed by the same letter in the column do not differ statistically from each other by the F test at 5% probability level.

μS.cm^{-1}.g^{-1}, and the treatments raw sample (T0) and lower discharge of the gravity table (T9) had the lowest and highest values, respectively.

According to Haesbaert et al. (2017), higher values of electrical conductivity are related to a greater release of exudates to the external environment through the cell membrane, indicating that the seeds are more deteriorated. Therefore, the higher values found in the lower discharge of the gravity table (T9) indicate that the seeds of this treatment show possible damage to these structures, thus corroborating the results obtained in the germination test.

Most of the seeds from the T9 sampling point are immature, defective, light and malformed. Immature, defective and malformed seeds have deficient organization of their cell membranes and, therefore, allow greater release of leachate into the solution in the electrical conductivity test (Gonçalves et al., 2015). Except for T9, the raw sample treatment (T0) did not differ statistically from the other stages, highlighting that the machines did not affect the electrical conductivity throughout processing.

Table 4 also shows that the variables accelerated aging, seedling emergence and emergence speed index did not differ as a function of the processing stages, with mean values of 71.25%, 55.0% and 10.8, respectively. The accelerated aging test is important to determine which seeds are more vigorous and therefore more tolerant to high air temperatures and relative humidity (Araújo et al., 2021), while the seedling emergence test is important to predict seed behavior in the field, where the conditions are not always favorable.

The results of viability (TZVB), vigor (TZVG), mechanical damage (TZMD) and seeds without damage by the tetrazolium test (SWoD) for chickpea seeds are described in Table 5. There was no statistical difference ($p > 0.05$) in any of these variables. The mean values of viability (TZVB), vigor (TZVG), mechanical damage (TZMD) and seeds without damage (SWoD) were 99.6, 66.9, 73.3 and 24.7%, respectively. The results of viability by the tetrazolium test (TZVB) did not correspond to those of germination, which showed lower means, regardless of the treatment evaluated. This is related to the cultivar BRS Cícero, which, due to its characteristics (genetic quality, intrinsic to the cultivar, and large seeds, hence more susceptible to mechanical damage), has shown lower physiological quality (germination) when compared to other chickpea cultivars, such as BRS Aleppo (Dias et al., 2019).

Table 5. Viability (TZVB), vigor (TZVG), mechanical damage (TZMD) and seeds without damage (SWoD) by tetrazolium test according to stages of processing of chickpea seeds, cultivar BRS Cícero.

Treatment	TZVB*	TZVG**	TZMD**	SWoD**
	(%)	(%)	(%)	(%)
T0-raw sample	100 a	68 a	84 a	16 a
T1-elevator 1	100 a	66 a	79 a	21 a
T2-12 mm sieve	100 a	58 a	85 a	15 a
T3-7.5 mm sieve	100 a	73 a	69 a	31 a
T4-elevator 2	100 a	69 a	67 a	33 a
T5-storage silo	99 a	60 a	73 a	27 a
T6-upper discharge	100 a	72 a	67 a	33 a
T7-high intermediate discharge	100 a	62 a	78 a	22 a
T8-low intermediate discharge	97 a	71 a	66 a	33 a
T9-lower discharge	100 a	70 a	65 a	16 a
Mean	99.6	66.9	73.3	24.7

*Means followed by the same letter in the column do not differ statistically from each other by the Kruskal-Wallis test at 5% probability level; **Means followed by the same letter in the column do not differ statistically from each other by the F test at 5% probability level.

It was observed that, regardless of the processing stages, the chickpea seeds already had high levels of initial mechanical damage, which is related to the harvesting process. To have quality seeds, a good regulation of the harvester to reduce the level of damage during harvest and threshing is of paramount importance (Holtz and Reis, 2013). In addition, the regulation must be adjusted according to the crop, genetic material and seed moisture content. It is also known that chickpea seeds, as well as common bean and soybean seeds, for having the embryonic axis relatively close to the external surface and a not very thick seed coat, are quite susceptible to mechanical damage (Pinto et al., 2012; Neves et al., 2016).

The effects of mechanical damage to seeds are immediate or latent. Immediate ones are easily characterized by naked-eye observation of broken seed coats and separated and/or broken cotyledons. In latent ones, there are microscopic cracks and/or abrasions or internal damage in the embryo, where germination may not be immediately affected, but the vigor, storage potential and performance of the seed in the field are reduced (Holtz and Reis, 2013).

With the results of the present study, the importance of processing in improving the physical and physiological characteristics of chickpea seeds has been proved. It was observed that this process is fundamental to increase the physical purity of the lot, especially the gravity table, more specifically the high intermediate discharge and the upper discharge, T7 and T6, respectively, which are in general the points of greatest gains. For soybean and common bean, it was observed that seeds discharged in the upper part of the discharge zone of the gravity table had significantly higher physical and physiological qualities than seeds discharged in the middle and lower parts (Buitrago et al., 1991; Moreano et al., 2013), results similar to those of the present study. Although the processing contributes to improving the physiological quality of the seed lot, it is known that this characteristic is determined in the field and not in the seed processing units.

CONCLUSIONS

Seed processing using air screen machine and the gravity table is efficient for improving the physical and physiological quality of the lot of chickpea seeds, cultivar BRS Cícero.

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