Engenharia Agrícola

ISSN: 1809-4430 (on-line)

www.engenhariaagricola.org.br

Scientific Paper

Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v43n2e20220138/2023

PHYSIOLOGICAL QUALITY OF PROCESSED, REPROCESSED, AND STORED SORGHUM SEEDS: IMPACT OF A DENSIMETRIC TABLE

Erica de F. Cabral[1*], Osvaldo Resende[1], Daniel E. C. de Oliveira[2], Lílian M. Costa[1], Jonathas L. R. dos Santos[1]

[1*]Corresponding author. Federal Institute of Education, Science and Technology Goiano-Campus of Rio Verde/Rio Verde - GO, Brazil. E-mail: ericafcabral@gmail.com | ORCID ID: https://orcid.org/0000-0002-9116-4531

KEYWORDS

Sorghum bicolor L. Moench, processing, apparent specific mass.

ABSTRACT

Sorghum (*Sorghum bicolor* L. Moench) is a crop of paramount importance for Brazil, used in human and animal food. Considering the reduced number of studies on the influence of using a densimetric table in seed processing and its respective reprocessing to the equipment, this study aimed to evaluate the physiological quality of processed sorghum seeds reprocessed in a densimetric table and stored for three months. The treatments consisted of four collection points in the terminal part of the densimetric table, representing the processing material: upper part (P1), upper middle part (P2), middle part (P3), and lower part (D). Subsequently, the samples that were reprocessed in the table came from P3 and were divided into the upper part, which was followed to bagging (P3R1), and the lower part (P3R2), which followed for disposal, totaling six treatments. Storage was performed in a refrigerated environment, using a completely randomized design, with the means being compared by Tukey's test at 5%. We concluded that the reprocessing of sorghum seeds in the densimetric table can improve the physical quality of a lot due to its standardization at the end of the stages, contributing to the improvement of the physiological quality and use of the material that would be discarded. The equipment performance allows the removal of seed fractions with lower apparent specific mass and promotes positive stratifications in the physiological quality of sorghum seed lots.

INTRODUCTION

Sorghum is a resilient cereal crop well-suited for drought-prone regions, displaying remarkable adaptability to environmental stress and variable rainfall patterns. Dahunsi et al. (2019) highlighted the extensive usefulness of sorghum, including its stem, grains, leaves, and various applications such as human consumption, animal feed, biofuel production, and forage utilization.

Several factors must be considered when choosing the best seed for planting, such as climate, soil, handling, and postharvest, due to the great economic importance of this product for farmers, and seed quality is essential for achieving high yields in a growing season (Elmasry et al., 2020).

According to Melo et al. (2016), the seeds enter the processing unit after harvesting with an uneven presentation, in addition to having a lot of impurities, which must be improved during the process to meet the commercialization for domestic and international markets and sowing.

The basic equipment of a seed processing unit is an air machine and sieves, a size classifier, a format separator, and a densimetric table, which separates seeds by specific mass. This equipment is essential to add value and quality to the final product (Araujo et al., 2011).

The densimetric table has become one of the main pieces of equipment in the seed processing unit due to its assertiveness in separating seeds from the upper part, which have the best quality in lots, and seeds from the lower part, which are sent to disposal, as they may be contaminated with fungi or by insect bites (Gadotti et al., 2012).

In this context, this study aimed to evaluate the physiological quality of processed sorghum seeds reprocessed in a densimetric table and stored for three months.

[1] Federal Institute of Education, Science and Technology Goiano-Campus of Rio Verde/Rio Verde - GO, Brazil.
[2] Federal Institute of Education, Science and Technology Goiano-Campus of Iporá/Iporá - GO, Brazil.

Area Editor: Paulo Carteri Coradi
Received in: 8-24-2022
Accepted in: 5-18-2023

MATERIAL AND METHODS

The experiment was carried out at the Laboratory of Postharvest of Plant Products of the Federal Institute of Education, Science, and Technology of Goiás, Campus Rio Verde, GO, Brazil, in partnership with the company Sementes Goiás Ltda., located in the municipality of Rio Verde, GO, on the highway GO 174 km 03 on the left, Zona Rural. The seeds were cleaned in an air and sieve machine, then followed to artificial drying in stationary dryers, reaching a final moisture content of around 10.5% wb. Subsequently, the seeds were taken for processing, proceeding with the classification by size through a 3.5-mm round opening sieve, followed by the MG-120 densimetric table with a rectangular format and a nominal capacity of 7 t hour^{-1}.

Processing samples were taken from two upper spouts of the densimetric table at point 1 (P1) and point 2 (P2), which were intended for bagging and represented the upper part of the table. The intermediate spout, at point 3 (P3), represents the middle part of the table, which goes to a bag through a conveyor screw and a diversion to be reprocessed later. The lower spout represents the lowest part of the table and goes to the disposal (D), as shown in Figure 1.

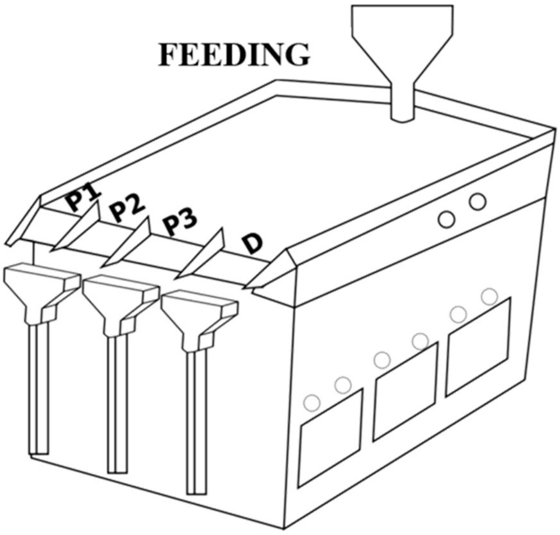

FIGURE 1. Densimetric table set to the seed processing.
Source: Prepared by the authors.

The sample that was sent to the densimetric table came from P3 after processing, generating two divisions, that is, P3R1, which followed to bagging, and P3R2, which followed to disposal, as shown in Figure 2.

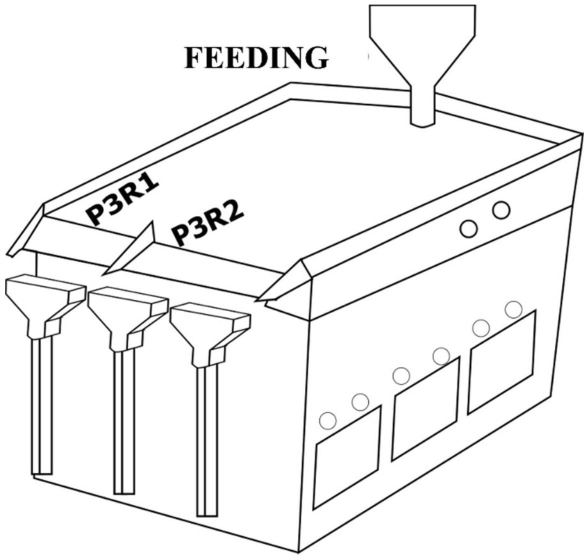

FIGURE 2. Densimetric table set to the seed reprocessing.
Source: Prepared by the authors.

Sampling was conducted by taking three replications at regular intervals of 60 min. The samples collected from each treatment were packed in single paper packaging with only one sheet and a 1.0-kg capacity and stored in a refrigerated warehouse (mean temperature of 13.99 °C and mean RH of 63%). The following evaluations were carried out on the seeds: moisture content, electrical conductivity, first germination count test, total germination, germination speed index, non-germinated seeds, normal seedlings, abnormal seedlings, normal seedling length, dry mass, seedling emergence in sand, emergence speed index, accelerated aging accounting for normal seedlings, non-germinated seeds, total germination, and abnormal seedlings, and moisture content at 0 and 3 months of storage, with temperature and relative humidity of the environment monitored hourly by digital sensors.

The moisture content test was performed using samples submitted to the standard method in an oven at 105 ± 3 °C for 24 h, with three replications of 15.0 g (Brasil, 2009). The electrical conductivity (EC) test was conducted according to Vieira & Krzyzanowski (1999). EC was read using a portable conductivity meter, with the reading expressed in $\mu S\ cm^{-1}\ g^{-1}$.

The first germination count (FGC) test was conducted with four subsamples of 50 seeds on Germitest paper towel rolls in a Mangelsdorf germinator set to maintain a constant temperature of 25 ± 1 °C. The amount of added water was equivalent to 2.5 times the mass of the dry substrate. The evaluations were conducted from the 4th day after sowing, according to the criteria established in the Rules for Seed Testing (Brasil, 2009). The total germination (TG) was performed ten days after sowing by adding the first and second counts. Non-germinated seeds (NGS) were counted at the end of the germination test (Krzyzanowski, et al., 1991).

Together with the germination test, normal seedlings (NS), abnormal seedlings, and normal seedling length (NSL) were determined on the fourth day after sowing. Normal seedlings were those with a developed root system and shoot, in addition to a minimum size of one centimeter; abnormal seedlings were those with the absence of the shoot and root system, with a length smaller than one centimeter; and normal seedling length consisted of the counting of 15 normal seedlings, as described by Silva et al. (2016). The counting of normal seedlings (NS) and abnormal seedlings (AS) was performed from the fourth day after sowing (Krzyzanowski et al., 1991).

Normal seedling dry mass (DM) was determined after obtaining the normal seedling length. These seedlings were packed in kraft paper and dried in a forced-air circulation oven at 65 °C for 72 hours (Nakagawa, 1999).

The germination speed index (GSI) was measured in a gerbox and calculated by the sum of seeds germinated daily above 1 cm from the 1st day of sowing and the germination in the days elapsed (Maguire, 1962).

Seedling emergence in sand (SES) was performed according to Silva et al. (2016), with four samples of 50 seeds per lot. This test was performed together with the emergence speed index (ESI), which was determined considering the number of seedlings that emerged daily with the leaf primordia above the substrate, calculated according to Maguire (1962). The normal seedling length was determined together with ESI and SES on the 14th day after sowing, using the following criteria: complete, proportional, and healthy plants with well-developed essential structures (root system and shoot) and higher than and equal to 9 cm (Brasil, 2009).

Accelerated aging (AE) was conducted with four subsamples of a uniform seed layer placed on wire mesh in plastic boxes (Gerbox) with 40 mL of distilled water at the bottom and maintained in a BOD at 43 °C for 72 h (Miranda et al., 2001). The germination test was carried out after the aging period, with evaluation four days after sowing and recording the percentage of normal seedlings (Krzyzanowski et al., 1991). The moisture content of seeds after the aging period was also determined to verify the uniformity of the test conditions, according to Mendonça et al. (2008).

The experiment was set up using a completely randomized design in a 6 x 2 factorial scheme, (six processing treatments at different points on the densimetric table during processing and reprocessing x two storage times), with three replications.

RESULTS AND DISCUSSION

In the climate-controlled seed storage environment, the overall mean temperature was 13.9 °C and relative humidity was 63.0% (Fig. 1). August had the lowest storage temperature (10.3 °C), but the minimum monthly means were recorded in August, September, and October, with values of 13.30, 13.23, and 13.94 °C, respectively, and the maximum monthly mean of 15.51 °C was recorded in November. The maximum mean recorded for relative humidity was 65.0% in November and the minimum means were 59.0, 62.0, and 64.0% in September, August, and October, respectively. October had a minimum relative humidity of 33.5% and a maximum of 90.7%.

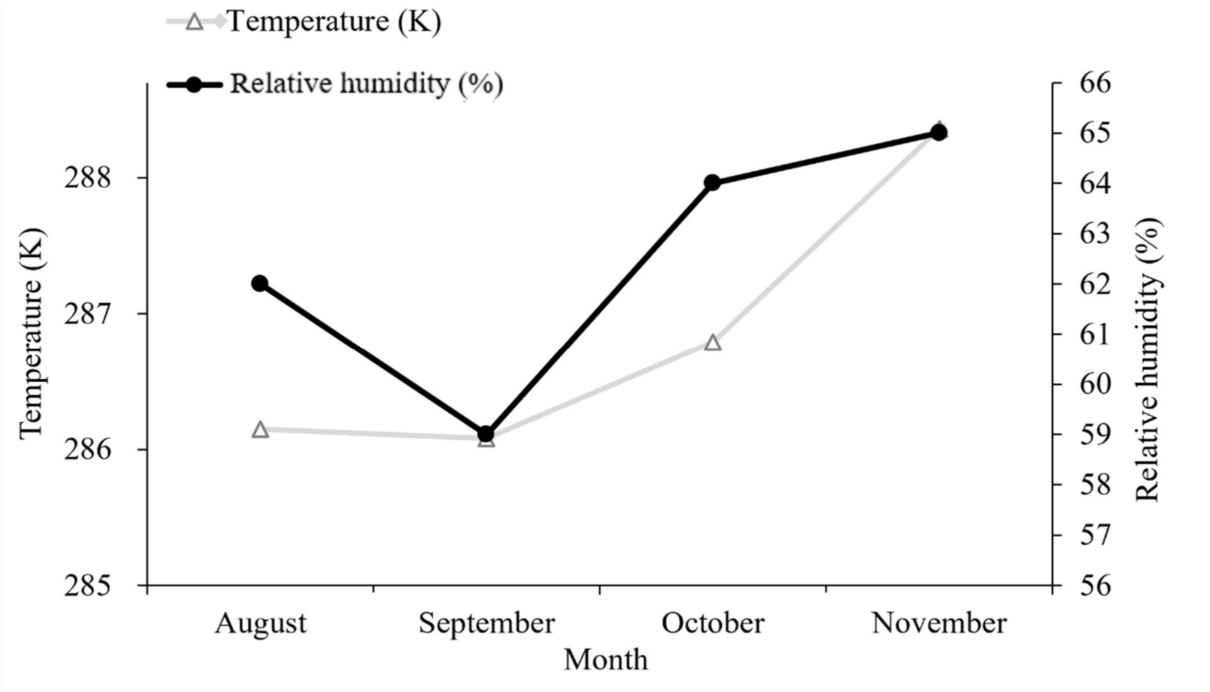

FIGURE 3. Mean temperature (°C) and relative humidity (%) of the refrigerated warehouse where the sorghum seeds were stored.

The observed temperature changes occurred as a result of climate changes in the environment, which reached the peak of the seed dispatch process during the period of maximum, thus achieving higher movement within the warehouse where the samples were stored. In addition, these temperature and relative humidity oscillations directly influence the initial seed characteristics, as mentioned by Oliveira et al. (2015), who emphasized the importance of preserving seed quality, keeping the metabolic activity, relative humidity, and temperature low.

Table 1 shows the analysis of variance and coefficients of variation corresponding to the analyzed variables in terms of sorghum seed processing including the reprocessing, resulting in six treatments and three months of storage in a refrigerated warehouse, as well as their possible interactions.

TABLE 1. Summary of analysis of variance for sorghum seeds.

Variables		Source of variation	Mean squares	CV (%)	
				1	2
Moisture content (% wb)	-	Treatment	0.19*		
	-	Months	0.84**	1.93	1.93
	-	Treatment x months	0.12^{NS}		
Electrical conductivity ($\mu s\ cm^{-1}\ g^{-1}$)	-	Treatment	6057.8**		
	-	Months	99.73**	7.50	7.46
	-	Treatment x months	39.69*		
Germination (%)	1st count	Treatment	3275.5**		
		Months	$0,44^{NS}$	2.70	3.45
		Treatment x months	4.14^{NS}		
	Total	Treatment	3227.1**		
		Months	0.56^{NS}	2.89	3.07
		Treatment x months	5.24^{NS}		
GSI (dimensionless)	-	Treatment	139.88**		
	-	Months	103.65**	7.89	9.1
	-	Treatment x months	3.37^{NS}		
Seedlings (%)	Normal	Treatment	2481.62**		
		Months	3.67^{NS}	12.9	14.58
		Treatment x months	26.72^{NS}		
	Abnormal	Treatment	2481.62**	12.9	14.58
		Months	3.67^{NS}		
		Treatment x months	26.72^{NS}		
Normal seedling length (cm)	-	Treatment	0.45^{NS}	-	-
	-	Months	7.88**	7.33	6.3
	-	Treatment x months	0.61*	-	-
Normal seedling dry mass (g)	-	Treatment	0.002**	14.83	17.75
	-	Months	0.004**		
	-	Treatment x months	0.001*		
Non-germinated seeds (%)	-	Treatment	3160**		
	-	Months	1.56^{NS}	10.09	11.6
	-	Treatment x months	7.88^{NS}		

**Significant at 1%; *Significant at 5%; NS Not significant by the F-test. CV: Coefficient of variation.

Table 2 shows the moisture content (MC) values of sorghum seeds during storage. The initial mean of MC of seeds stored at the initial time was 12.10% (wb), showing a decrease during storage for all treatments due to exchanges of water vapor with the environment. A difference can be observed between treatment P1 (upper part of the table) and treatment D (lower part of the table), that is, a higher moisture content for the latter treatment.

TABLE 2. Moisture content (% wb) for sorghum seeds.

Treatment	Storage time (months)		Mean
	0	3	
P1	11.85	11.43	11.64a
P2	11.99	11.71	11.85ab
P3	12.05	12.02	12.04ab
D	12.54	11.75	12.15b
P3R1	11.97	11.96	11.97ab
P3R2	12.19	11.87	12.03ab
Mean	12.09B	11.79A	-

Means followed by lowercase letters in the column and uppercase letters in the row differ statistically by the Tukey test at 5%.

The decrease in moisture content during storage may be related to storage conditions, as a gradual increase in temperature and a decrease followed by an increase in relative humidity (RH) was observed (Fig. 1). Moreover, the stored packages had high permeability (single-layer paper bags), causing the exchange of water vapor between the seeds and the external environment. Williams et al. (2017) studied the storage of sorghum seeds in fabric bags, plastic soda bottles, and hermetic containers and observed no negative change in seed quality, but the high temperature and relative humidity in the environment reduced seed quality in the long-term quality, also emphasizing that seeds stored in inadequate packaging and environments will deteriorate and lose vigor.

The electrical conductivity (EC) of the sorghum seed solution showed an interaction between treatments and storage time (Table 3). The data show that P3, D, and P3R2 had higher values than P1, P2, and P3R1. According to Silva et al. (2017), the electrical conductivity test provides an assertive separation of the different seed vigor levels measured indirectly, in addition to determining the amount of leachate in the soaking solution. Data obtained by Drumond et al. (2019) reinforce that the growing increase in electrical conductivity compromises the physiological seed quality and vigor, causing a disorder of membrane cells, leaving the seeds more susceptible to external damage.

TABLE 3. Electrical conductivity (µS cm^{-1} g^{-1}) of the solution for sorghum seeds.

Treatment	Storage time (months)	
	0	3
P1	12.54 a A	12.80 a A
P3	44.7 c B	36.60 b A
D	102.78 d B	91.37 d A
P3R1	20.58 b A	19.57 a A
P3R2	48.03 c A	49.16 c A

Means followed by lowercase letters in the column and uppercase letters in the row differ statistically by the Tukey test at 5%.

Treatments D and P3R2 were sent directly for disposal and the results shown in Table 3 reinforce the high values of electrical conductivity for these treatments. Fessel et al. (2003) evaluated the physical and physiological quality of corn seeds during processing and observed that the increase in the leaching of metabolites, followed by the occurrence of mechanical damage, reduces seed vigor and germination. Nunes et al. (2017) determined the quality of bean seeds and observed that the higher the absolute value of electrical conductivity, the lower the vigor, and that the smaller amount of leachate in the solution indicates higher vigor, demonstrating a better structuring of membranes.

The higher the mean values of electrical conductivity, the worse the lot quality, showing that the disposals (D and P3R2) had better results than the others and, consequently, a higher degree of electrical conductivity. Soares et al. (2010) conducted a series of tests to evaluate the vigor of sorghum seeds with an emphasis on electrical conductivity and obtained higher precision to identify low vigor lots, as shown in the results of the present study for treatments P3R2 and D.

In general, the results of the germination test indicate that there were differences for all treatments (Table 4), showing the first germination count (FGC) and total germination (TG).

TABLE 4. Mean values of first germination count (FGC) and total germination (TG) for sorghum seeds.

Treatment	FGC (%)	TG (%)
P1	98.00a	98.33a
P2	95.75ab	95.83ab
P3	75.25c	76.08c
D	36.58e	37.25e
P3R1	92.67b	93.33b
P3R2	69.25d	70.25d

Means followed by lowercase letters in the column differ statistically by the Tukey test at 5%.

The mean of the first germination count had considerable values and, consequently, TG values (final count ten days after the test set up) were similar, as most of the seeds had already germinated, demonstrating the consistency of the tests. Treatments P1, P2, and P3R1 stand out according to the test, as they presented values consistent with the legislation, with the minimum germination standard recommended for the commercialization of sorghum seeds, which is established at 80% (Brasil, 2009). On the other hand, treatments P3, D, and P3R2 presented no minimum standard. Silva et al. (2016) reinforced the importance of numerous tests to assess seed quality, as the first count test indirectly evaluates the germination speed.

The function of the densimetric table is to separate the materials through differences in specific mass and size. Table 4 shows that treatments P1 and P2 had the highest germination values. The reprocessing of P3 led to a higher stratification of sorghum seeds in the densimetric table, with P3R1 values similar to those of P2.

GSI of sorghum seeds increased over the storage period, indicating influence for all treatments (Table 5). GSI aims to identify seeds with faster seedling emergence in the field or greenhouse. High germination speed indices were observed in treatments P1, P2, P3, and P3R1, while treatments D and P3R2 showed low GSI values. Drumond et al. (2019) analyzed the physiological quality of castor bean seeds after processing and found that seeds subjected to classification by a densimetric table had higher quality and higher values of germination speed index.

TABLE 5. Germination speed index (GSI) for sorghum seeds.

Treatment	Storage time (months)		Mean
	0	3	
P1	16.24	21.12	18.68a
P2	16.16	21.40	18.78a
P3	13.44	16.93	15.19b
D	5.70	7.02	6.36c
P3R1	16.71	19.83	18.27a
P3R2	12.01	14.31	13.16b
Mean	13.38A	16.77B	

Means followed by lowercase letters in the column and uppercase letters in the row differ statistically by the Tukey test at 5%.

Table 6 shows the difference between the analyzed treatments for non-germinated seeds. Samples D and P3R2 showed the highest percentage of non-germinated seeds, reinforcing that these seeds should be destined directly for disposal without prior evaluation.

TABLE 6. Mean values for non-germinated seeds (NGS), normal seedlings (NS), and abnormal seedlings (AS) for sorghum seeds.

Treatment	NGS (%)	NS (%)	AS (%)
P1	1.67e	73.00a	25.00ab
P2	4.17de	66.67ac	28.75ab
P3	23.92c	48.25b	26.75abc
D	62.08a	20.50d	16.08c
P3R1	6.75d	57.08bc	35.67ab
P3R2	29.83b	31.58d	37.67a

Means followed by lowercase letters in the column differ statistically by the Tukey test at 5%.

The analysis of the germination test and the results of the mean of normal and abnormal seedlings show that the mean number of NS and AS differed in all treatments (Table 6). Seeds identified as those with low vigor in most germination tests (D and P3R2) had lower percentages of NS compared to intermediate (P3 and P3R1) and high vigor (P1 and P2) lots. All treatments showed a difference regarding AS, with the reprocessing treatments (P3R1 and P3R2) showing a higher NS index compared to the other treatments.

The results referring to normal and abnormal seedlings in the present study corroborate Santos Neto et al. (2012), who evaluated the use of the densimetric table in improving the quality of commercial castor bean seeds and identified that the upper part of the table had more vigorous seeds and a higher percentage of emergence. Javorski & Cicero (2017) evaluated the internal morphology of sorghum seeds with an x-ray and observed that abnormal seedlings or dead seeds originate from damage due to tissue deterioration in sorghum seeds.

The variable normal seedling length showed no differences between treatments, but an effect of storage time was observed, with a decrease in NSL according to time (Table 7).

TABLE 7. Mean values (%) of normal seedling length (NSL) for sorghum seeds.

Treatment	Storage time (months)	
	0	3
P1	6.75b	5.73a
P2	6.73b	5.36a
P3	6.76b	5.61a
D	6.74a	6.94a
P3R1	7.06b	5.47a
P3R2	6.64a	5.95a

Means followed by lowercase letters in the row differ statistically by the Tukey test at 5%.

Almeida et al. (2016) analyzed the quality of soybean seeds processed in a densimetric table and found that the total seedling length showed no interaction between the evaluated factors, showing that the processing of soybean seeds in a densimetric table did not influence the increase in seedling length. Félix et al. (2017) stored *Adonidia merrillii* seeds and found that seedling length had a progressive decrease with the advancing storage period, confirming the results of this study. Macedo et al. (2020) evaluated the physical and physiological quality of safflower seeds submitted to processing in a densimetric table and identified that the total seedling length may be related to seed density, specific mass, and thousand-seed mass.

The evaluation of normal seedling dry mass (DM) was carried out together with the NSL. This variable showed a difference between treatments and months of storage, with treatments P1, P2, and P3R1 presenting the highest DM mean (Table 8).

Barbieri et al. (2013) found that seedlings with higher dry mass production have better physiological quality with high vigor, also producing more and accumulating more dry matter than those with medium vigor.

TABLE 8. Dry mass (g seedling^{-1}) for sorghum seeds.

Treatment	Storage time (months)	
	0	3
P1	0.11 a A	0.14 b B
P2	0.11 a A	0.14 b A
P3	0.09 a A	0.13 b B
D	0.09 a B	0.06 a A
P3R1	0.11 a A	0.14 b A
P3R2	0.08 a A	0.10 ab A

Means followed by lowercase letters in the column and uppercase letters in the row differ statistically by the Tukey test at 5%.

According to Nakagawa (1999), a higher weight of seedlings is related to dry matter accumulation. Therefore, seeds are more vigorous, making a higher transfer of mass from their reserve tissues to the embryonic axis.

Seedling emergence in sand (SES) and emergence speed index (ESI) showed an effect of treatments and storage time alone (Table 9), whereas normal seedling length (NSL) had an interaction between the evaluated factors. In accelerated aging, the variables normal seedlings (NS), non-germinated seeds (NGS), and total germination (TG) were significant for treatment and storage time at 1% significance, with the variables abnormal seedlings (AS) and moisture content (MC) showing the interaction between treatments and months at 1% significance.

TABLE 9. Summary of variance analysis for seedling emergence in sand for sorghum seeds.

Test in sand				
Variable	Source of variation	Mean squares	CV (%)	
			1	2
Seedling emergence in sand (SES) (%)	Treatment	3584.0**	6.19	6.19
	Months	203.06**		
	Treatment x months	21.38^{NS}		
ESI (Dimensionless)	Treatment	884.47**	5.58	5.58
	Months	79.35**		
	Treatment x months	6.08^{NS}		
NSL (cm)	Treatment	3034.3**	0.00	0.00
	Months	1338.34**		
	Treatment x months	281.69**		
Accelerated aging				
NS	Treatment	1763.36**	16.02	11.92
	Months	981.78**		
	Treatment x months	45.24^{NS}		
AS	Treatment	359.21**	24.11	16.63
	Months	177.78**		
	Treatment x months	82.79**		
NGS	Treatment	3538.23**	-	-
	Months	324.00**	18.93	21.37
	Treatment x months	28.08^{NS}	-	-
TG	Treatment	3538.23**	6.75	7.62
	Months	324.00**		
	Treatment x months	28.08^{NS}		
MC	Treatment	3.27**	0.00	0.00
	Months	39.36**		
	Treatment x months	4.38**		

**Significant at 1%; *Significant at 5%; NS Not significant by the F-test. CV: Coefficient of variation.

Three vigor levels were identified In both the seedling emergence in sand (SES) and accelerated aging tests (Tables 10). Treatments P1, P2, and P3R1 consist of lots that are above the commercialization standard for sorghum seeds according to Normative Instruction No. 45 MAPA – 2013. Seed fractions in treatment D showed lower quality than the other treatments because they are located in the lowest part of the table. Gadotti et al. (2020) studied the efficiency of the densimetric table in processing coriander seeds and found that seeds from the upper, middle high, and middle discharges had a higher degree of viability compared to the lower part of the table, corroborating this study.

TABLE 10. Mean values of seedling emergence in sand, accelerated aging, and emergence speed index in sand for sorghum seeds.

Treatment	(% SES)	(% AE)	(ESI)
P1	92.75a	94.72a	43.83a
P2	91.00a	92.67a	44.00a
P3	65.17b	69.75b	30.11b
D	30.58c	30.83c	13.95c
P3R1	90.25a	89.17a	43.87a
P3R2	62.00b	65.50b	28.90b

Means followed by lowercase letters in the column differ statistically by the Tukey test at 5%.

The emergence speed index allowed separating the discharged seeds in the densimetric table, originating from processing and reprocessing, into three vigor levels, with superiority in seeds from the upper part of processing and reprocessing (P1, P2, and P3R1), also showing inferiority for seeds from the lower part (D and P3R2). Similarly, Pereira et al. (2012) observed that seeds collected in the upper discharge of the gravitational table had a higher emergence speed index, which shows the function of the densimetric table in increasing the viability of the seeds being processed.

CONCLUSIONS

The seed processing is assertive to carry out the separation of sorghum seeds regarding their quality. The reprocessing of the material in the densimetric table can also improve the physical quality of a lot due to the standardization at the end of the steps and increase the viability of seed lots being processed, contributing to improving the physiological quality of the product and allowing the use of the material that would otherwise be discarded.

The equipment allowed the removal of seed fractions with lower apparent specific mass and promoted positive changes in the physiological quality of sorghum seed lots.

ACKNOWLEDGEMENTS

The authors thank the IF Goiano, CAPES, FAPEG, FINEP, and CNPq for financial support, which was indispensable to conducting this study.

REFERENCES

Almeida T, Capilheira A, Araújo J, Scheunemann L, Panozzo Le (2016) Qualidade de sementes de soja beneficiadas em mesa de gravidade. Enciclopédia Biosfera 13(23): 1097-1106. https://doi.org/10.18677/Enciclopedia_Biosfera_2016_093

Araujo RF, Araujo EF, Zonta JB, Vieira RF, Donzeles SML (2011) Fluxograma de beneficiamento para sementes de feijão-mungo-verde (Vigna radiata L.). Revista Brasileira de Sementes 33:387-394. https://doi.org/10.1590/S0101-31222011000300001

Barbieri M, Dutra CB, Bianchini NH, Muniz MFB, Dörr AC (2013) Análise de desenvolvimento a campo e avaliação de massa seca e massa verde de plantas de aveia preta cv. Comum (Avena Strigosa Schreb). Revista Eletrônica em Gestão Educação e Tecnologia Ambiental 11(11):2407-2412. http://dx.doi.org/10.5902/223611708803

BRASIL. Ministério da Agricultura Pecuária e Abastecimento Secretaria de Defesa Agropecuária (2009) Regras para análise de sementes. Brasília, Mapa/ACS. 399p. Available: https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/arquivos-publicacoes-insumos/2946_regras_analisesementes.pdf. Accessed Feb 14, 2021.

Dahunsi SO, Adesulu-Dahunsi AT, Osueke CO, Lawal AI, Olayanju TMA, Ojediran JO, Izebere JO (2019) Biogas generation from Sorghum bicolor stalk: effect of pretreatment methods and economic feasibility. Energy Reports 5:584-593. https://doi.org/10.1016/j.egyr.2019.04.002

Drumond AAL, Sales JF, Zuchi J, Camelo GN, Souza MMV (2019) Qualidade fisiológica de sementes de mamona (Ricinus communis L.) após o beneficiamento. Journal of Seed Science 41(2):224-232. https://doi.org/10.1590/2317-1545v41n2215551

Elmasry G, Elgamal R, Mandour N, Gou P, Al-Rejaie S, Belin E, Rousseau D (2020) Emerging thermal imaging techniques for seed quality evaluation: principles and applications. Food Research International 131:109025. https://doi.org/10.1016/j.foodres.2020.109025

Félix FC, Santos AF dos, Santos FC dos, Pacheco MV (2017) Dessecação e armazenamento de sementes de Adonidia merrillii (Becc.) Becc. Revista Brasileira de Ciências Agrárias 12(1):86-91. DOI: https://doi.org/10.5039/agraria.v12i1a5421

Fessel SA, Sader R, Paula RC, Galli JA (2003) Quality evaluation of corn seeds during conditioning. Revista Brasileira de Sementes 25(2):70-76. https://doi.org/10.1590/S010131222003000400001

Gadotti GI, Baudet L, Villela FA (2012) Several regulations in gravity table in quality of tobacco seeds. Engenharia Agrícola 32(2):361-368. DOI: https://doi.org/10.1590/S0100-69162012000200016

Gadotti GI, Hornke NF, Cavalcante JA, Silva JG, Gonçalves VP, Capilheira AF (2020) Eficiência da mesa de gravidade no beneficiamento de sementes de coentro. Horticultura Brasileira 38(2):211-216. https://doi.org/10.1590/S0102-053620200214

Javorski M, Cicero SM (2017) Utilização de raios x na avaliação da morfologia interna de sementes de sorgo. Revista Brasileira de Milho e Sorgo 16(2):310-318. https://doi.org/10.18512/1980-6477/rbms.v16n2p310-318

Krzyzanowski FC, França-Neto JB, Henning AA (1991) Relato dos testes de vigor disponíveis para as grandes culturas. Embrapa Soja-Artigo em periódico indexado (ALICE). Publisher: Informativo ABRATES Brasília 1(2):15-50. Available: http://www.alice.cnptia.embrapa.br/alice/handle/doc/444400

Macedo VGK, Dörr CS, Gularte JA, Marques FS, Panozzo LE (2020) Qualidade física e fisiológica de sementes de cártamo submetidas ao beneficiamento em mesa de gravidade. Brazilian Journal of Animal and Environmental Research 3(3):992-1005. https://doi.org/10.34188/bjaerv3n3-020

Maguire JD (1962) Speed of germination—aid in selection and evaluation for seedling emergence and vigor. Crop Science 2(1):176-177. https://doi.org/10.2135/cropsci1962.0011183X000200020033x

Melo LF, Martins CC, Silva GZ, Boneti JEB, Vieira RD (2016) Beneficiamento na qualidade física e fisiológica de sementes de capim-mombaça. Revista Ciência Agronômica 47(4): 667-674. Available: http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/4580

Mendonça EAF, Azevedo SC, Guimarães SC, Albuquerque MCFE (2008) Testes de vigor em sememtes de algodoeiro herbáceo. Revista Brasileira de Sementes 30(3):9.

Miranda DM, Novembre ALC, Chamma HMCP (2001) Avaliação do potencial fisiológico de sementes de sorgo pelo teste de envelhecimento acelerado. Revista Brasileira de Sementes 23(1):226-231.

Nakagawa AJ (1999) Testes de vigor baseados no desempenho de plântulas. Vigor de sementes: conceitos e testes. ABRATES 2:1-24.

Nunes RTC, Souza UO, Bandeira AS, Santos JL, Morais OM, Gomes MF (2017) Qualidade de sementes de Vigna unguiculata classificadas em diferentes tamanhos. Revista Cultura Agronômica 26(1):1-9. https://doi.org/10.32929/2446-8355.2017v26n1p1-9

Oliveira LM, Schuch LOB, Bruno RLA, Peske ST (2015) Qualidade de sementes de feijão-caupi tratadas com produtos químicos e armazenadas em condições controladas e não controladas de temperatura e umidade. Semina: Ciências Agrárias 36(3):1263-1275. https://doi.org/10.5433/1679- 0359.2015v36n3p1263

Pereira CE, Albuquerque KS, Oliveira JA (2012) Physical and physiological rice seed quality in the processing operation. Semina: Ciências Agrárias 33(6): 2995-3002. https://doi.org/10.5433/1679-0359

Santos Neto ALD, Carvalho MLMD, Oliveira JA, Fraga AC, Souza AAD (2012) Uso da mesa densimétrica na melhoria da qualidade de sementes comerciais de mamona. Revista Brasileira de Sementes 34: 549-555. https://doi.org/10.1590/S0101-31222012000400004

Silva RS, Vendruscolo TPS, Castrillon MA, Luz PB, Lima CC, Barelli MAA (2016) Qualidade fisiológica de sementes de sorgo biomassa (Sorghum bicolor L. Moench). Revista Espacios 37(31):1909-1913. Available: http://www.revistaespacios.com/a16v37n31/16373112.html

Silva TM, Lopes MFQ, Oliveira AB, Nogueira ALSP, Viana IET, Lessa BFT (2017) Physiological quality of sweet sorghum [Sorghum bicolor (L.) Moench.] seeds in response to planting density in semi-arid region. Australian Journal Crop Science 11(6):694-700. https://doi.org/10.21475/ajcs.17.11.06.p420

Soares MM, Conceição PM, Dias DCF, Alvarenga EM (2010) Vigor tests in sorghum seeds with emphasis to electrical conductivity. Ciência e Agrotecnologia 34(2):391-397. https://doi.org/10.1590/S1413-70542010000200017

Vieira RD, Krzyzanowski FC (1999) Teste de condutividade elétrica. Vigor de sementes: conceitos e testes. ABRATES 1:1-26.

Williams SB, Murdock LL, Baributsa D (2017) Sorghum seed storage in Purdue Improved Crop Storage (PICS) bags and improvised containers. Journal of Stored Products Research 72:138-142. https://doi.org/10.1016/j.jspr.2017.04.004