Comparison between devices for homogenization and reduction of soybean grain samples

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Abstract

In the grain market the most diverse equipment is used for homogenization and reduction of the working samples. Thus, this paper aims to analyze the performance of devices used for sample homogenization and reduction for soybean classification. A sample composed of 8% of damaged soybeans with yellow and black coat was previously prepared. Samples were homogenized and reduced in bucket, crate, Boerner, 16:1 multichannel splitter and 4:1 multichannel splitter. The design used was completely randomized with five treatments (homogenizers) and one percentage of damaged grains (8%). Evaluations were subjected to analysis of variance and treatment means were compared to one another by Tukey test ($p \leq 0.5$) and to the mean of the original sample (8%) by Student's t-test. The devices Boerner, 16:1 multichannel splitter and 4:1 multichannel splitter were similar in the homogenization and reduction of the soybean sample. The crate and bucket showed the worst performance in the grain homogenization because they compromise the result of the product's qualitative analysis.

Keywords: Classification; *Glycine max*; homogenizers; official standard; quality.

1. Introduction

Over the years, soybean has stood out as the main crop in Brazil (Almeida et al. 2016; Carvalho et al. 2017). It is the crop with largest extension of cultivated area (Trautmann et al. 2014) and greatest economic expression, generating income and development in the regions of cultivation (Freitas 2011). In the 2019/20 season, the total production of soybeans in the country was around 120.09 million tons (CONAB 2020), which ranks Brazil as the world's largest producer of oilseeds.

There are elements that, combined, form the global competitiveness and determine the capacity of the soybean-producing country to maintain or expand its potential for participation in the world market. Among these elements, it is possible to cite price competitiveness, logistics, exchange rate policy, technology adopted and quality of products (Sampaio et al. 2012).

Evaluation of grain quality, checking for defects in soybean, allows to characterize the attributes, levels of damaged grains and also to determine the use according to the needs of each food chain associated (Lorini 2016).

Toxin detection process is complex and consists of three fundamental steps: collect the sample from the lot, prepare the material and collect subsamples for analysis, besides the quantification process (analysis) (Whitaker et al. 2011). There is a similarity in the process for classification of soybean grains, which also has three distinct stages: representative sampling of the grains of a lot, homogenization and satisfactory reduction into subsamples, which will be sent for classification (analysis), according to the parameters

established in the Normative Instruction nº 11/2007 of the Ministry of Agriculture, Livestock and Food Supply (Brazil 2007).

In an analysis, the sample should be obtained so that all grains that make up the lot have the same chance to be selected (Whitaker 2003). Sampling efficiency can be estimated by evaluating the variation of the results generated and by the adopted procedures of detection (Mallmann et al. 2013; Mallmann et al. 2014). For that, in the homogenization and reduction step, it is fundamental to use devices that keep the characteristics reliable, even at lower proportions, for the analysis of the attributes of the lot.

According to the norm of the International Standard Organization (ISO 2009), the composite sample must be fully homogenized before any procedure of division for analysis, and this norm establishes that the division of the working sample without previous homogenization leads to samples that do not represent the original lot.

In Brazil, the Normative Instruction (NI) MAPA nº 29/2011 (Brasil 2011a) recommends, as mandatory requirement to meet the certification of storage units, that it is necessary to have a homogenization system, without discriminating which device should be. The NI MAPA nº 11/2007 (Brasil 2007) establishes that the sample intended for classification should be homogenized and reduced by quartering, without mentioning which device would be recommended.

Given the above, this study aimed to analyze the performance of devices used to homogenize and reduce samples for the classification of soybean grains in storage units.

2. Material and Methods

The samples were prepared at the Laboratory of Postharvest of Plant Products of IF Goiano – Campus of Rio Verde – GO, Brazil, and at the Storage Unit of Caramuru Alimentos, municipality of Rio Verde, GO.

Damaged grains were simulated using soybeans with black coat (Figure 1), with moisture content of 10.7% (wet basis), which were added to the samples of product with yellow coat, with moisture content of 11.2% (w.b.), according to the method of ASAE (2003).

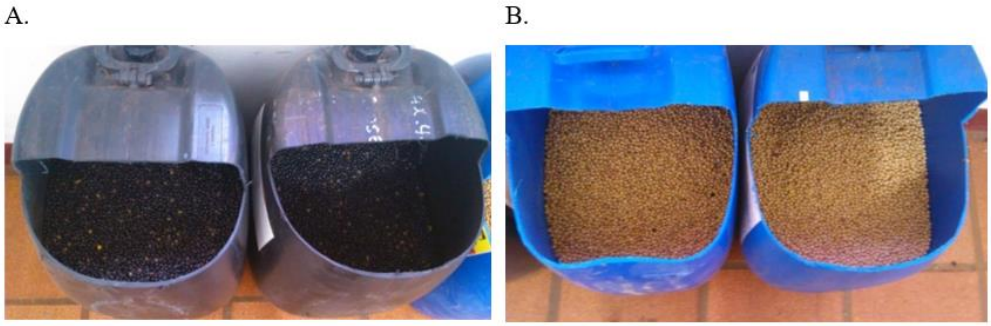

Figure 1. Samples of soybean grains with black coat (A) and yellow coat (B).

Soybeans with yellow coat and black coat were evaluated for bulk density, which was determined using a container with known volume (1 L), filled with grains of both coat colors in different lots, with a fixed falling height of 0.225 m. After filling and weighing, bulk density was determined based on the ratio between mass (kg) and volume (m^3) on semi-analytical scale. The results were 751.7 ± 1.90 kg m^{-3} and 748.7 ± 4.96 kg m^{-3} for yellow and black soybeans, respectively.

Procedures of uniformization and standardization of grain size were carried out by passing samples of soybeans with black and yellow coat through a sieve with 7.0-mm-diameter circular apertures.

Soybean samples were previously prepared with a level of 8% of damaged grains, represented by soybean with black coat.

Increments (primary sample) were prepared by taking the proportion of soybeans with yellow and black coat, and the samples were placed in a 2.10-m-long sampler with one opening stage.

The sampler had 14 intakes, with capacity for 0.9 kg of soybean. For the filling with grains, the sampler was positioned vertically with the intakes closed and the samples were proportionally inserted through the upper end, alternating a quantity of mass of soybean with black coat and another with yellow coat. The 8% level of damaged grains was achieved by adding 0.072 kg of soybean with black coat and 0.828 kg of soybean with yellow coat, divided into 14 parts, which corresponded to the number of intakes of the sampler.

Then, the manually-operated double-tube sampler was directly unloaded into a bucket. Each sampler unloaded was considered as an increment (a sampling point). For each replicate, a sequence of 11 increments was carried out to simulate 11 sampling points, as established in the NI MAPA nº 11/ 2007 (Brasil 2007), obtaining a composite sample of 9.9 kg.

The level of damaged grains (soybean with black coat) was evaluated using a minimum mass of 0.125 kg, according to NI MAPA nº 11/2007. For each device tested, 9 repetitions were performed.

Subsequently, these samples were homogenized and reduced in five devices: bucket with capacity for 12 kg, wooden crate (0.4 m wide x 0.6 m long x 0.2 m high), Boerner divider, 16 x 1 multichannel splitter, 4 x 1 multichannel splitter (Figure 2).

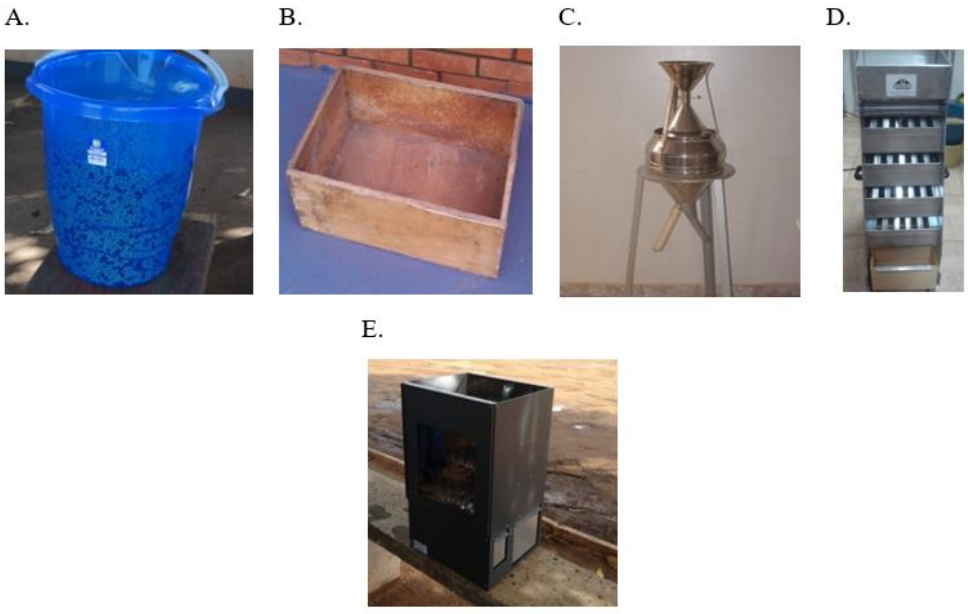

Figure 2. Illustration of the devices used for sample homogenization and reduction: (A) bucket; (B) wooden crate; (C) Boerner divider; (D) 16:1 multichannel splitter and (E) 4:1 multichannel splitter.

The 16:1 multichannel splitter is 0.32 m wide, 0.6 m long and 1.20 m high, consisting in the assembly of small splitters (stages), one below the other, from the discharge hopper of the device (Figure 3A).

The first and third splitters have 12 channels (six for the sample and six for the reject) with mean width of 25.39 mm, whereas the second and fourth splitters have 11 channels (six for the reject and five for the sample) with mean width of 25.30 mm and larger lateral channels, 39.18 mm. As the discharge hopper opens, the product crosses the first splitter, one part of it is intended for the sample and the other part is discarded, and so on until the subdivision to the container of the working sample, and the other part, of larger volume, for the reject (Figure 3A).

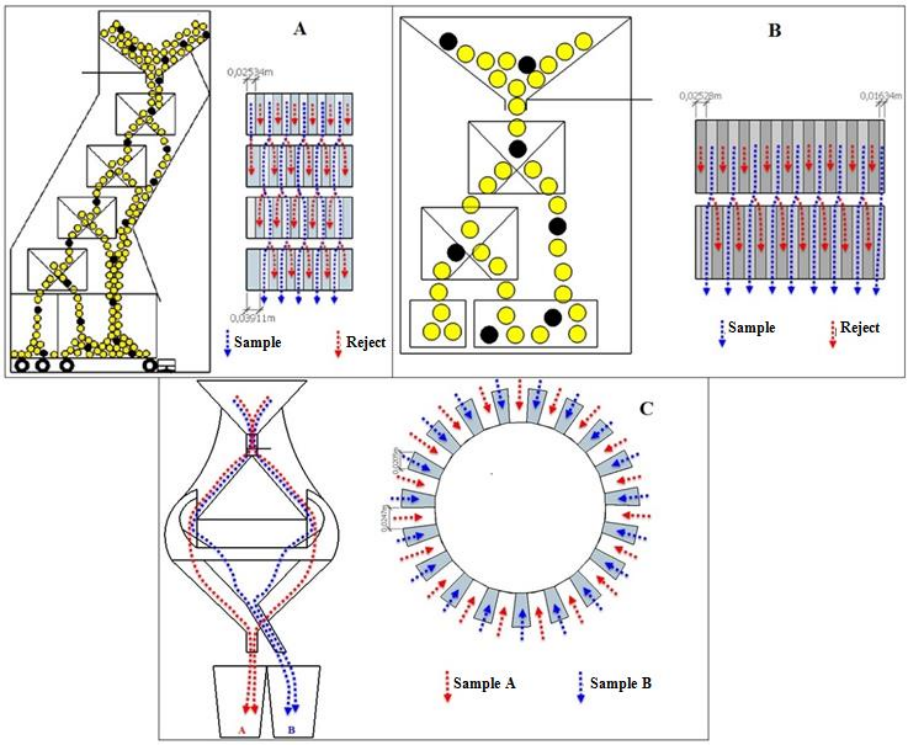

Figure 3. Scheme of homogenization, reduction and dimensions of the channels for the 16-channel splitter (A); 4-channel splitter (B) and Boerner divider (C).

The 4:1 multichannel splitter is 0.45 m wide, 0.41 m long and 0.64 m high, and consists in the assembly of two smaller splitters (stages), one on top of the other. The first one is formed by 18 channels (nine for the sample with mean width of 25.25 mm, plus a lateral channel with 16 mm width, and also nine channels for the reject with mean width of 25.25 mm), as illustrated in Figure 3B. This first splitter reduces and takes part of the sample to the reject, and the sample passes through a second splitter with 17 channels (9 channels for the sample and 8 for the reject), which also divides the grains, one part is discarded and the other part is used for the working sample. In this device, it is necessary to pass the grains more than once to reduce the working sample.

The Boerner divider has a hopper to pour the sample equipped with a valve that opens when one wants to perform the operation of homogenization. Grains pass through a funnel and randomly fall into an inverted cone which redistributes these grains along a diameter of 0.36 m, composed of a set of internal channels with 20.5 mm width and external channels with 24.7 mm width, which are directed to the internal and external funnels, and the samples are stored in containers. At least two homogenization procedures are

necessary (CANADA 2016) and only then the reductions are performed. Several passes are required depending on the final mass of the working sample (Figure 3C).

Figure 4 presents the sequence of procedures for homogenization and preparation of soybean grain samples.

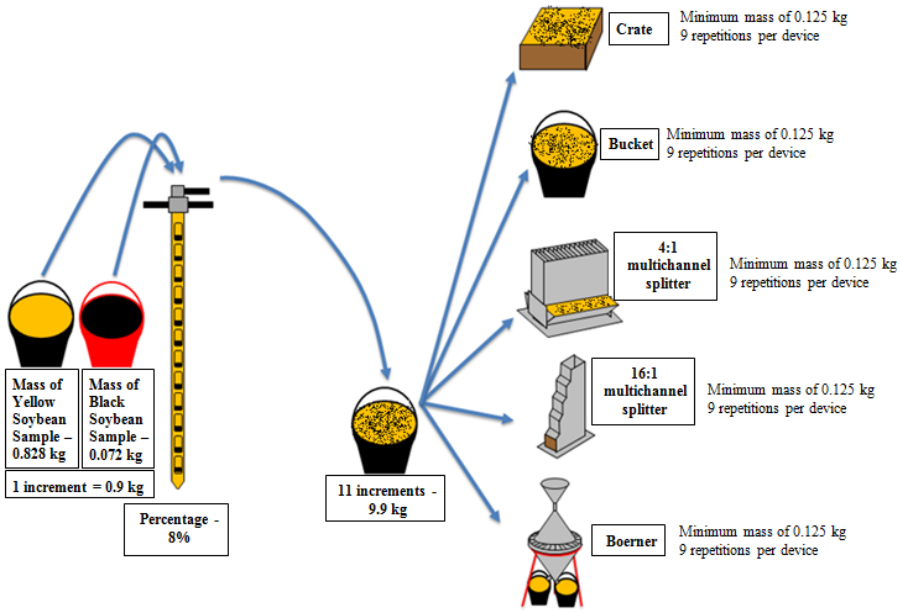

Figure 4. Schematic representation of the procedures of one repetition for homogenization of soybean grains.

For the Boerner divider and the 4:1 and 16:1 multichannel splitters, each sample was passed once for homogenization and then divided into three equal parts and put into buckets. Each bucket was considered as one replicate of the device. These samples were passed in the homogenizing device until a mass of at least 0.125 kg was obtained, according to the NI MAPA nº 11/2007, collecting three replicates for each device and each replicate with three subsamples which were identified, totaling nine replicates per device. For homogenization in the bucket, each replicate was manually homogenized always by the same operator, in the same container, and three subsamples were collected from each replicate, also totaling 9 replicates of at least 0.125 kg. For the crate, the sample was homogenized always by the same operator using a concave object with dimensions of 0.012 m x 0.006 m and in diagonal with 0.02 m depth. Such homogenization was carried out with horizontal movements in the longitudinal and transverse directions of the crate. After homogenization, the samples were collected using a concave object, weighed and identified.

After homogenization, the working samples with at least 0.125 kg, according to the NI MAPA nº 11/2007, were analyzed for the percentage of damaged grains (black coat).

Evaluations were performed in a completely randomized design, with five treatments corresponding to the homogenizers (bucket, crate, Boerner, 16:1 multichannel splitter, 4:1 multichannel splitter) and one percentage of damaged grains (8%), with minimum grain mass in the working sample of 0.125 kg, in nine repetitions. The results were compared to the original sample previously prepared with 8% of damaged grains.

The results were subjected to analysis of variance (ANOVA) and F test. Means of treatments (devices) were compared to one another by Tukey test and to the mean of the original sample (8%) by the two-tailed Student's t-test.

2. Results and Discussion

Table 1 presents the percentage of damaged grains collected after homogenization in the different devices evaluated for homogenization and division of samples.

Table 1. Means, coefficient of variation and p-value by t-test for damaged grains (% black soybean) collected in the samples after homogenization in the different devices evaluated.

Treatment	Means	C.V. (%)	t-test
Bucket	5.87 b	7.70	0.0000**
Crate	5.79 b	14.78	0.0001**
Boerner	7.89 a	10.38	0.690
16:1 Splitter	8.29 a	5.09	0.079
4:1 Splitter	8.37 a	11.30	0.283

Means followed by the same letter in columns do not differ at 0.05 significance level by Tukey test; C.V.: Coefficient of variation; (p-value) for the t-test; **Contrast relative to the original mean (8%), significant at 0.01 probability level by t-test (p-value).

It can be noted that the crate and the bucket did not differ with respect to the mean percentage of damaged grains by Tukey test at 0.05 significance level and showed greater discrepancies in comparison to the original sample prepared with 8% of damaged grains, both underestimating the actual value. Based on the t-test, the means of these two devices differed from that of the original sample prepared with 8% of damaged grains, at 0.01 significance level (Table 1).

The bucket and crate did not show satisfactory results for homogenization and reduction of the samples of damaged grains and are extremely dependent on handling. The operators may even be tendentious, although involuntarily, during the homogenization and collection of the working sample, which may lead to biased estimates.

The crate showed the highest CV among the devices used in the experiment, whereas the bucket and 16:1 splitter showed lower coefficients of variation. However, the bucket also showed a substantially lower mean compared to the original mean of 8%, and the Boerner and 4:1 splitter showed CV of 10.38% and 11.30%, respectively, and the most satisfactory means in comparison with the original value of 8%, being more adequate in the operations of homogenization and reduction, corroborating with Quirino et al. (2019). Lower percentages of damaged grains found in the bucket and crate indicate that these devices may cause loss for the parts involved in the commercialization, when used for homogenization and reduction of grains, despite using the sample size recommended by the NI MAPA nº 11/2007 (Brasil 2007).

The greatest difference from the original sample with 8% of damaged grains occurred for the crate (5.79%), which represents an error of 27.66%, followed by the bucket (5.87%), with error of 26.65% in comparison

to the expected mean.

These results were expected and show the inefficacy of utilization, in procedures of homogenization and reduction of composite sample, of methods that favor the interference in the handling by the operator, subject to the working environment conditions, physical fatigue during the work day, heterogeneity in the loads coming directly from the fields (Wagner & Esbensen 2014), and the subjectivity in the form of moving the grain mass and collecting the sample, in detriment of the representativeness of the working sample, which will be used to determine the quality of the original lot.

The devices Boerner, 16:1 multichannel splitter and the 4:1 multichannel splitter did not differ by Tukey test at 0.05 significance level and also did not differ from the mean of the original sample prepared with 8% of damaged grains by t-test at 0.05 significance level. In addition, these devices were the closest ones to the original sample, prepared with 8% of damaged grains (Table 1).

Although there was no difference between the Boerner and the 16:1 and 4:1 multichannel splitter, the mean of the Boerner device was closer to that of the original sample (8.0%), despite showing lower CV than the 4:1 multichannel splitter. Considering two decimal places, there were differences of 1.43% for the Boerner and of 3.62% and 4.58% for the 16:1 and 4:1 multichannel splitters, respectively (Table 1). The Boerner divider was the closest one and, like the 16:1 and 4:1 multichannel splitters, it also did not differ significantly ($p \leqslant 0.05$) by t-test from the mean originally prepared and expected. The Boerner divider has been the favorite for utilization in several scientific studies (Fonseca 2002; Al-Mahasneh & Rababah 2007).

The Boerner-type sample homogenizer and divider is the only device approved for homogenization and division of samples by the Canadian Grain Commission (CANADA 2016). The norm ISO 24333 (ISO 2009) indicates for grains not only the Boerner divider, but also the quartering iron (surface), quartering dividers (multiple grooves) with at least 18 channels, and also the mechanical centrifugal divider for small samples.

The RY 1075/94 norm XXII (SENASA 1994) of Argentina recommends that sample homogenization and division should be carried out using the Boerner device or a similar one that produces a similar result. The United States Department of Agriculture (USDA 2009) recommends the use of the Boerner homogenizer and divider or any other device that gives equivalent results when reducing the sample in size and accuracy level required.

The NI MAPA nº 29/2011 (Brasil 2011a) establishes that all storage units should have for certification a homogenization system. In addition, the current Normative Instructions in Brazil describe that the samples should be homogenized and quartered (Brasil 2007; Brasil 2011a). However, none of these instructions establishes the adequate equipment for this commercial operation, and these results may contribute to reviewing the norm. In Brazil, only the NI MAPA nº 54/2011 establishes and demands the use of homogenization equipment for the operations in which the official classification is mandatory (Brasil 2011b).

In relation to the use of devices which require less interference from the operators (Boerner and 4:1 and 16:1 multichannel splitters), the Boerner divider requires higher number of passes of the same sample to attain the required working mass, needs a longer time for homogenization and emits high level of noise in the operation room.

The 4:1 multichannel splitter requires higher number of passes than the 16:1 multichannel splitter and makes the work slower. However, both splitters emit a tolerable level of noise, much lower for the 16:1 multichannel splitter, which requires lower number of passes according to the size of the working sample used. Consequently, this device requires shorter time to prepare the sample.

5. Conclusion

The homogenizing and reducing devices Boerner, 16:1 multichannel splitter and 4:1 multichannel splitter are similar in the reduction and homogenization of soybean grain samples, using the sample size established by the NI MAPA nº 11/2007.

For commercial operations, we recommended the use of Boerner divider and multichannel splitters with reductions of 4:1 and 16:1.

The devices crate and bucket show unsatisfactory performance compared to the original sample with 8% of damaged grains and are not adequate for homogenization and reduction of grain samples, because they compromise the results of the product's qualitative analysis.

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