Corn seeds of different sizes under drying methods and storage periods

Sementes de milho de diferentes tamanhos sob métodos de secagem e períodos de armazenamento

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ABSTRACT
The seed is the main input in the production process of the corn crop, and the drying process is crucial for maintaining the physiological quality and longevity of the seeds. Thus, the present study aimed to evaluate the physiological potential of hybrid corn seeds retained in different sieves under drying methods and storage periods. The experiment was conducted with corn seeds of the hybrid Balu 280 PRO, in a completely randomized design, with eight replications of 50 seeds, in a $5 \times 2 \times 2$ factorial scheme, with retention sieves (24 M, 22 M, 20 M, 18 M, and 20
R), drying methods (traditional drying and gas drying) and storage periods (0 and 365 days). The variables analyzed were viability and vigor, based on germination and cold tests, respectively. Data were submitted for variance analysis using the F test (p<0.05) and means were compared using the Tukey test (p<0.05). For non-stored seeds, traditional and gas drying methods are independent for maintaining the viability and vigor of corn seeds. For seeds under 1 year of storage, the traditional drying method is better than gas drying to maintain the physiological quality of corn seeds, but the commercial standard is maintained in both methods. In both traditional and gas drying methods, seed storage favors the reduction of germination and vigor of corn seeds. Seeds retained on 22 M, 20 M, and 20 R sieves have greater vigor when compared to seeds retained on 18 M sieves.

**Keywords:** *Zea mays*, germination, viability, vigor, physiological quality of seeds, gas drying.

**INTRODUCTION**

Corn (*Zea mays* L.) is a grass belonging to the Poaceae family, originally from the Americas. It is one of the most cultivated cereals in the world, being one of the pillars of Brazilian agriculture, with an approximate cultivation area of 22 thousand hectares and production of 126 thousand tons, considering the 1st, 2nd, and 3rd harvests (CONAB, 2023). Therefore, obtaining high-quality seeds is extremely important, considering that they are linked to high rates of vigor,
germination, and health, in addition to ensuring physical and varietal purity. All these factors culminate in the response of the seed in the field, ensuring a quality stand with good performance and high levels of production (PELISSARI and COIMBRA, 2023).

It is known that the seed is an important input in agriculture, given that it is responsible for establishing the plant stand in the field. The production of high-quality seeds requires care from the management of the crop to the harvest, as well as in the post-harvest stages, such as processing, drying, and storage. It is recommended to harvest them as close to physiological maturity, when the maximum physiological potential is reached, avoiding seed storage in the field, to reduce qualitative and quantitative losses, since the delay in harvesting contributes considerably to its deterioration. However, the unevenness of maturation makes it difficult to determine this phase, which may increase the predisposition to injuries in the seeds due to their high humidity (ASSIS et al., 2023).

Harvesting seeds with humidity above the recommended level for safe storage has become a common practice among producers, since, remaining in the field after physiological maturity, they are exposed to unfavorable environmental conditions, and the alternating processes of sorption and desorption of water inside can cause irreversible physical and physiological damage, in addition to the risk of higher incidences of pests and diseases. Seeds with high humidity have high respiratory activity and consequent consumption of reserves that can lead to physiological wear that, in practice, will result in reduced germination and vigor rates. Anticipating the harvest of seeds with higher humidity makes it possible to reduce the risks of deterioration, in addition to the possibility of planning the harvest, less loss due to natural dehiscence, the flexibility of processing structures, better crop rotation planning, and optimization of the use of production fields (OLIVEIRA et al., 2021).

In addition, by minimizing the factors that reduce seed quality in the field phase, the preservation of seed quality is also dependent on drying and storage conditions (AMARO et al., 2019). Therefore, there must be good planning from the time of planting, so that, during the harvest period, the seeds are not exposed to the weather for a long time and that the drying process occurs in a coordinated manner. The drying process has contributed to maintaining the quality of the seeds, as it allows anticipating the harvest and maintaining the initial quality of the seeds during storage. However, it is necessary to carefully plan and execute the drying process, especially when harvested seeds have high humidity, as the vapor pressure gradient between the
interior and the drying air can increase during this process. This results in high drying rates, i.e., a high percentage of water removed in a shorter period, in addition to a high probability of injury to cell structures, which will consequently contribute to quality loss.

However, despite the advantages that artificial drying presents, depending on how it is carried out, it can be a source of damage to the seeds, therefore, it deserves special attention on the part of the producers. Its susceptibility to drying damage is a function of processing conditions, its quality at the time of drying, and initial humidity, combined with genetic aspects. Due to these factors, the seeds respond differently to the drying processes, that is, to the temperature, the exposure time to this temperature, and the speed of removal of water. Therefore, it is desirable that efforts via genetic improvement are not only aimed at increasing productivity but also consider the post-harvest phase, since this stage completes the production system, thus deserving special attention (OLIVEIRA et al., 2021).

Currently, the heated air drying system is the system most used by seed companies, as it allows greater control of drying regardless of environmental conditions, in addition to drying large volumes of seeds in a shorter period and the possibility of monitoring the entire drying process, starting from the initial humidity (OLIVEIRA et al., 2021). Among the methods used for corn cultivation, the gas drying method has allowed a greater flow of raw material from the field to the Seed Processing Unit (SPU), as it frees up space in the stationary drying chambers when they reach the moisture that makes threshing possible, with subsequent transfer to the gas dryer, where the drying process will be completed. However, the participation of this process in maintaining seed quality and longevity is little known, as well as its viability in relation to the traditional method.

Therefore, it is extremely important to evaluate the effectiveness of drying methods in maintaining seed quality, considering that seed moisture is directly related to the occurrence of mechanical damage, whether immediate or latent, which is favored by levels of humidity lower than 11% and higher than 15%, respectively. The main source of mechanical damage is the harvesting operation, although a large part of this damage may result from drying, processing, and sowing operations, given that the moisture in the seeds is not at the ideal level for carrying out these operations, which in turn contributes to the vigor reduction (FRANÇA NETO and HENNING, 1984; FRANÇA NETO et al., 2021).

In this context, drying is an extremely important process for the seed production chain,
contributing to maintaining their quality by reducing moisture to appropriate levels for processing and storing seed batches. Therefore, for better use of equipment and efficiency of the drying process for the corn crop, which is usually carried out in cobs, the present study aimed to evaluate the physiological potential of hybrid corn seeds retained in different sieves under drying methods and storage periods.

2 MATERIAL AND METHODS

The experiment was conducted with corn seeds of the hybrid Balu 280 PRO, from the second harvest of 2015, grown in the municipality of Pitangueiras-PR (Brazil), at the Alto Alegre farm (latitude 23°13’ S, longitude 51°35’ O and altitude of 660 m), under center pivot irrigation. The base fertilization consisted of 400 kg ha\(^{-1}\) of NPK and two top-dressing fertilizations of 150 kg ha\(^{-1}\) of nitrogen when the plants had four and six expanded leaves.

The cobs were harvested and transported to the Sementes Balu unit in Arapongas-PR (Brazil) for the processing and drying process. The experiment was conducted in a completely randomized design, with eight replications of 50 seeds, in a 5 × 2 × 2 factorial scheme, with retention sieves (24 M, 22 M, 20 M, 18 M, and 20 R), drying methods (traditional drying and gas drying) and storage periods (0 and 365 days).

For the traditional drying method, the cobs were dried using stationary drying chambers with a capacity of 30 tons, using a furnace with an indirect fire system at a temperature of 40°C until a humidity of 11% was obtained, and then the threshing. In the gas drying method, the cobs were dried to 15% moisture (as described in the previous method), followed by threshing and sending the seeds through a conveyor belt to the indirect fire stationary gas dryer (Dryeration\(^{®}\)) with a capacity of 30 tons. On that occasion, the seeds were dried at 40°C to 11% moisture.

After drying, threshing, and cleaning the seeds, they were classified by retention in five sieves – 24 M (medium), 22 M (medium), 20 M (medium), 18 M (medium), and 20 R (round), treated with a commercial dose of Maxim\(^{®}\) XL (1.000 L.t\(^{-1}\)), Actellic\(^{®}\) 500 EC (0.016 L.t\(^{-1}\)) e K-obiol\(^{®}\) 25 EC (0.040 L.t\(^{-1}\)) and packaged in multilayer paper bags. Then, the seeds were placed in a warehouse without climate control, to evaluate two storage periods – 0 and 365 days of storage.
After the seeds were submitted to the treatments, they were taken to the Technology and Seed Production Laboratory of the State University of Londrina (UEL) for the evaluation of the variables according to the following tests:

- **Germination test**: eight experimental units of 50 seeds were placed between three sheets of germitest paper moistened with distilled water with a volume equivalent to two and a half times the mass of the substrate. The paper rolls were placed in a germinator at 25°C and the evaluation of normal seedlings was performed on the seventh day after the installation of the test (BRASIL, 2009). The results were expressed in percentage of germination (%) – viability.

- **Cold test**: eight experimental units of 50 seeds were placed in rolls of germitest paper moistened with distilled water with a volume equivalent to two and a half times the mass of the substrate. Then, the rolls were placed in a transparent plastic bag, sealed with adhesive tape, and placed in a BOD incubator at 10°C for seven days (BARROS et al., 1999). After this period, each experimental unit was removed from the plastic bag and placed in a germinator at 25°C; performing the count of normal seedlings after four days (BRASIL, 2009). The results were expressed in percentage of vigor (%).

The basic assumptions were previously verified for the validity of the results obtained in the individual analysis of variance, using the Shapiro-Wilk test, at 5% significance to verify normality, and the Bartlett test at 5% significance to verify homogeneity of residual variances. Subsequently, the data were submitted for variance analysis using the F test (p<0.05), and the means were compared using the Tukey test, at a 5% error probability.

### 3 RESULTS AND DISCUSSION

The triple interaction between the factors “retention sieve”, “drying method” and “storage period” was not significant for any of the analyzed variables. The germination variable showed significant differences in the interaction between the factors “retention sieve” and “drying method”, and between “drying method” and “storage period”. The variable vigor showed significant differences for the interaction between the factors “drying method” and “storage period”, and for the isolated factor “retention sieve” (Table 1).
Table 1. Analysis of variance for germination and vigor variables of corn seeds retained in different retention sieves under drying methods and storage periods.

<table>
<thead>
<tr>
<th>Sources of variations</th>
<th>Germination</th>
<th>Vigor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention sieve (RS)</td>
<td>16.962667**</td>
<td>22.845281**</td>
</tr>
<tr>
<td>Drying method (DM)</td>
<td>39.214001**</td>
<td>72.200000**</td>
</tr>
<tr>
<td>Storage period (SP)</td>
<td>554.667781**</td>
<td>827.798445**</td>
</tr>
<tr>
<td>RS × DM</td>
<td>8.590945*</td>
<td>4.921113ns</td>
</tr>
<tr>
<td>RS × SP</td>
<td>4.582781ns</td>
<td>6.801226ns</td>
</tr>
<tr>
<td>DM × SP</td>
<td>39.186001**</td>
<td>53.366445**</td>
</tr>
<tr>
<td>RS × DM × SP</td>
<td>0.033501ns</td>
<td>5.858945ns</td>
</tr>
<tr>
<td>Residue</td>
<td>3.222224</td>
<td>4.855557</td>
</tr>
<tr>
<td>CV (%)</td>
<td>1.94</td>
<td>2.43</td>
</tr>
</tbody>
</table>

*Significant at 1% probability; † Significant at 5% probability; *ns Not significant.
Source: Author

According to Table 2, it is possible to observe the interaction between the factors “retention sieve” and “drying method” for the germination variable. When using the traditional drying method, there is no significant difference in the percentage of germination according to the retention sieves; for gas drying, the size of the seeds needs to be considered. According to Lunedo et al. (2023), seed size is an important variable for obtaining stand uniformity, to avoid double plants or distribution failures. In this way, the authors found in their study that the classification through the retention of sieves is a relevant characteristic at the time of sowing, improving the sowing distribution, in addition to providing parameters to obtain a final production of the highest quality.

Table 2. Germination of corn seeds selected by different retention sieves under drying methods.

<table>
<thead>
<tr>
<th>Retention sieve</th>
<th>Traditional drying</th>
<th>Gas drying</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 M</td>
<td>93.33 Aa</td>
<td>91.00 BCb</td>
</tr>
<tr>
<td>22 M</td>
<td>94.16 Aa</td>
<td>93.16 Aa</td>
</tr>
<tr>
<td>20 M</td>
<td>94.00 Aa</td>
<td>93.00 ABa</td>
</tr>
<tr>
<td>18 M</td>
<td>92.50 Aa</td>
<td>90.00 Ch</td>
</tr>
<tr>
<td>20 R</td>
<td>94.33 Aa</td>
<td>92.16 ABCb</td>
</tr>
</tbody>
</table>

Distinct uppercase letters in columns and lowercase letters in lines differ by Tukey's test at 5% significance.
Source: Author

The seeds retained on the 22 M and 20 M sieves do not show the difference in the germination rate for the two evaluated drying methods; on the other hand, the 24 M, 18 M, and 20 R sieves contribute to the increase in the percentage of germination with the drying of the seeds by the traditional method (Table 2). According to Vasquez et al. (2012), changes in the size of corn seeds interfere only with the initial development of the plants, because after 40 days of
emergence, the height of the plants and the insertion of the first cob, the diameter of the stem, the number of grains per cob, the weight and size of the grain and grain yield are not affected by the size and shape of the corn seed used in normal summer sowing. Alves et al. (2011) also found that seed size does not influence germination and initial development of corn seedlings of three varieties (white, dentate, and Flintisa), except root length.

In the present study, a relationship between seed size and drying method in the germination process was observed, and because classification and drying are part of corn seed processing, both factors must be taken into account in crop planning, bearing in mind that the germination rate is essential to obtain stand uniformity and optimize the seed production field, both for handling and for harvesting.

Table 3 shows the interaction between the factors “drying method” and “storage period” for the germination variable. Therefore, it is observed that for corn seeds that do not need to be stored, the drying process can be carried out either by the traditional method or by gas. However, for seeds that need to be stored for 365 days, drying using the traditional method is recommended, given that gas drying contributes to reducing the percentage of germination.

This fact can be explained by the fact that the traditional drying method obtained 11% moisture before threshing, which probably reduced the rate of damage to the seeds and, consequently, maintained higher germination than those that were gas-dried. In gas drying, the seeds were initially dried to 15% moisture, subsequently threshed, and sent by a conveyor belt to the gas dryer to reach 11% moisture. Such conditions contribute to the generation of mechanical damage, mainly. However, it is worth noting that even with the reduction in the germination rate under gas drying, both drying methods allowed obtaining a germination percentage higher than the minimum required for marketing corn seeds, which is 85% (BRASIL, 2009).

Table 3. Germination of corn seeds under drying methods and storage periods.

<table>
<thead>
<tr>
<th>Storage period (days)</th>
<th>Drying method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traditional drying</td>
</tr>
<tr>
<td>0</td>
<td>95.40 Aa</td>
</tr>
<tr>
<td>365</td>
<td>91.53 Ba</td>
</tr>
</tbody>
</table>

Distinct uppercase letters in columns and lowercase letters in lines differ by Tukey's test at 1% significance.

Source: Author

In addition, it is noted that in both drying methods, germination decreased when it went from 0 to 365 days under storage (Table 3). According to Elias (2008), gradual increases in
humidity and temperature, under certain storage conditions, originate a set of specific and cumulative physical-chemical processes in grain deterioration, which is correlated with microbial development and the appearance of pests during storage. Therefore, the way of storage and the type of drying are important in the quality of the seed for the maintenance of germination and vigor.

In this way, as the reduction of moisture under gas drying was prolonged compared to the traditional one, the probability of increased damage in the first one was also reflected in the viability of the seeds that were stored (Table 3), remaining longer under the effect of latent damage, which favors an increase in the respiratory rate and a reduction in the vigor of the lots (Table 4).

Regarding seed vigor, evaluated from the cold test, an interaction between the factors “drying method” and “storage period” was also observed. Seeds submitted to storage for 365 days showed lower vigor when compared to non-stored seeds, in both drying methods. Seeds without storage showed no statistical difference in vigor between the drying methods, however, in seeds stored for 365 days, it was observed that gas drying contributed to the reduction of seed vigor when compared to traditional drying (Table 4).

Table 4. Vigor of corn seeds under drying methods and storage periods.

<table>
<thead>
<tr>
<th>Storage period (days)</th>
<th>Drying method</th>
<th>Traditional drying</th>
<th>Gas drying</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>94.20 Aa</td>
<td>93.93 Aa</td>
<td></td>
</tr>
<tr>
<td>365</td>
<td>89.40 Ba</td>
<td>85.86 Bb</td>
<td></td>
</tr>
</tbody>
</table>

Distinct uppercase letters in columns and lowercase letters in lines differ by Tukey's test at 1% significance.
Source: Author

Cunha et al. (2009) stated that storage is an important variable that can influence seed quality, mainly due to latent damage. Thus, from the evaluation of the vigor of seeds subjected to different drying methods and storage periods, it was observed that the reduction in vigor of stored seeds can be explained by the occurrence of latent damage during the processing and/or drying process. In addition, the effect of reduced vigor was greater in gas-dried seeds, since threshing occurred under conditions of higher humidity (15%) when compared to the traditional method (11% moisture). According to França Neto et al. (2021), both low and high seed moisture favor the occurrence of mechanical damage in processing and drying operations, which contributes to reduced vigor.
Regarding seed vigor, there is also an isolated effect of the “retention sieve” factor, with the seeds retained in the 18 M sieve (smaller size) having a lower percentage when compared to the 22 M, 20 M, and 20 R sieves (Table 5). According to Carvalho and Nakagawa (2012), smaller seeds tend to have less dry matter accumulation, which in turn limits the physiological potential, which is understood as the association between germination percentage and seedling vigor. Thus, with a lower accumulation of dry matter (limited reserves), the seeds have a lower capacity to synthesize photoassimilates, generating seedlings with lower vigor.

<table>
<thead>
<tr>
<th>Retention sieve</th>
<th>Vigor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 M</td>
<td>90.50 AB</td>
</tr>
<tr>
<td>22 M</td>
<td>91.74 A</td>
</tr>
<tr>
<td>20 M</td>
<td>91.75 A</td>
</tr>
<tr>
<td>18 M</td>
<td>88.91 B</td>
</tr>
<tr>
<td>20 R</td>
<td>91.33 A</td>
</tr>
</tbody>
</table>

Distinct uppercase letters in column differ by Tukey’s test at 1% significance.
Source: Author

Evaluating parameters that aim to optimize the flow of raw material receipt in the Seed Processing Units (SPU) is of paramount importance, especially during the harvest season. Thus, from the present study, the gas drying method proves to be a viable option for corn seeds that do not need to be stored, to provide the fastest freeing of space in the stationary drying chambers when they reach the humidity that allows threshing (15%), with subsequent transfer to the gas dryer, where the drying process will be completed (up to 11% humidity), taking into account the maintenance of viability and vigor of the lot. However, for corn seeds that need to be stored for one year, the traditional drying method is advantageous in maintaining the physiological quality when compared to the gas method.

It is worth emphasizing that the corn seeds, under all retention sieves, drying methods, and storage periods, evaluated in the present study, presented a germination rate greater than 85%, being able to be commercialized as seeds. Thus, the gas drying of corn seeds proves to be a viable option, since it allows a greater flow of raw material receipt from the field to the SPU, making more space available in the drying chambers more quickly, in addition to avoiding the exposure of seeds, in the field, to the weather and ensure better quality in the harvest, with less loss in the straw harvester.
4 CONCLUSIONS

For non-stored seeds, traditional and gas drying methods are independent for maintaining the viability and vigor of corn seeds.

For seeds under 1 year of storage, the traditional drying method is better than gas drying to maintain the physiological quality of corn seeds, but the commercial standard is maintained in both methods.

In both traditional and gas drying methods, seed storage favors the reduction of germination and vigor of corn seeds.

Seeds retained on 22 M, 20 M, and 20 R sieves have greater vigor when compared to seeds retained on 18 M sieve.
REFERENCES


