Effect of two drying processes about soybean seed quality

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Abstract: This work studies the effects of two drying processes on quality soybean seed. This study compares simultaneously the effects of two drying processes: the dry-aeration process and conventional drying process. Two drying temperatures (60°C and 80°C) and two tempering times (30 and 120 min) were investigated. The seed quality variables analyses were: tegument break and germinating power. Results show that both drying processes were negative effect on quality seed but dry-aeration process cause less damage. The dry-aeration process with lower temperature and higher tempering time caused less damage than conventional drying process about germinating power and tegument integrity of the soybean seed. In dry-aeration process, the highest tempering time (120 min.) shows a positive effect on soybean seed quality. For temperature analysis, the most relevant damage occurred at the highest temperature.

Keywords: dry-aeration, conventional drying, drying temperature, tempering time, soybean seed

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1 Introduction

Soybean oil production has gained great importance in Argentina and in the world for its high nutritional value. Because of this, the production of soybean seed gained great interest in covering large areas of land. The early harvest technique of seed makes seeds retain higher moisture and, thus, they should be dried through artificial drying. Moisture content for safe storage that could assure good quality is 10%-12% wet basis (w.b.) (Yang et al., 2015), while soybean seeds are harvested with a moisture content that ranges between 18%-16% (w.b.) or more. The moisture reduction by artificial drying is the preservation technique used more efficiently to prevent and / or minimize grain damage during storage (ASHRAE Handbook, 1997). It is a process of mass and heat transfer where heat vaporizes the water in the grain removing it with the drying air (Gely, 2002). In this work were analyzed two drying process of seed showed in Figure 1. The conventional drying processes for drying soybeans include a stage with high temperature air until the desired moisture content is reached, followed by second stage immediate cooling “in situ” with air at ambient temperature (Figure 1a). One disadvantage of this drying process is that the change in temperature during drying (hot-cold) damages product quality. Non-conventional drying process is the dry-aeration process. This is an alternative process to avoid damaging the seeds. The dry-aeration process involves an intermediate storage stage between high temperatures and cooling (Figure 1b.). This intermediate stage is called tempering and this is very important for homogenization of moisture inside seeds, as there is moisture diffusion from the interior to the external surface of the seed, this made easy eliminate the last point moisture. This stage has two objectives: reducing costs of drying process and keeping seed quality (Iguaz et al., 2006).

The soybean seed doesn’t have practically endosperm. It consists of a seed coat or integument and a very large embryo. This consists of two cotyledons and embryo axis. Because of grain morphology, mechanical damage that can be generated by bad practices during harvest and

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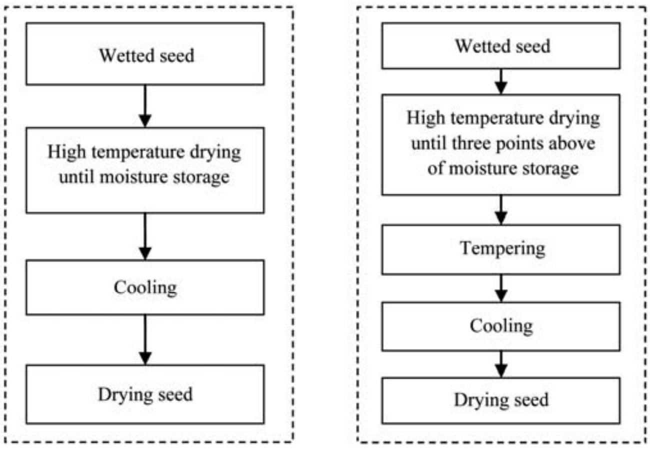
postharvest can determine the future inability to germinate (Casini, 2007). El-Abady (2014) studied the effect of temperature drying on high quality maize seed. This work analyzes the effect of drying in fast green test, standard germination, abnormal seedlings, speed of germination, cold test, electrical conductivity, shoot length, root length and seedling dry weight. The obtained results show the negative effect of high temperature drying on the seed. Dong et al. (2010) studied the effect of drying time and tempering time on fissuring the two variety rice. Their results show that shorter time drying and higher tempering time reduced the rice fissuring. Also, Iguaz et al. (2006) analyzed different drying processes on quality rice displayed that use of tempering time minimizes damage of grain. Devilla et al. (1999), in their study, displayed that dry-aeration process reduces the susceptibility of corn to damage.



a. Conventional drying b. Dry-aeration drying

Figure 1 Comparison of two drying processes

The objective of this study was to analyze the effects of dry-aeration process on the quality of soybean grain specifically on the break tegument and germinating power. Also it intends to compare these effects with the effects caused by conventional drying. This paper seeks to preserve the quality of soybeans seed once separated from the plant, achieving maximization of Argentina's agroindustrial productivity.

2 Experimental Section

2.1 Preparation and characterization of the sample

Soybean seeds (360 GR variety) from a 150 kg bag were conditioned and characterized. These seeds were harvested in summer 2006/2007, in the area of Olavarría, Argentina. Soybean seed had no drying treatment. The characterization analyses were: initial moisture of seeds, break tegument and germination power.

Initial moisture of seeds was determined by AOAC 14.003 (AOAC, 1990). This was analyzed by triplicate. In this analysis, a vacuum oven (40 cm Hg) was used at 110ºC until constant weight was reached, which was attained after about 8 h. Then, the seeds were wetted for analysis of the drying process.

Wetted soybean seed sample

Water was added to the soybean seeds to reach the moisture of 27% (w/w) (d.b.). Afterwards, seeds were stored for 48 h in closed containers at 8°C to homogenize the moisture inside the sample seeds. Wetting of the sample was performed in duplicate. The final moisture was analyzed according to method (AOCS Ba – 2b – 82) (AOAC, 1990).

Break tegument

The break tegument was determined by putting 10 seeds in a sodium hypochlorite solution 1% (w v^{-1}) for 10 minutes. Then, the swollen and translucent white seed were counted, value corresponding to the number of seed which break tegument (Gutormson, 1992). The ten repetitions were performed.

Germinating power

The germination seed power was determined following ISTAS 5.2.2 (2003) method. In order to standardize the internal conditions of the germination camera, the size of the sample was modified to 50 seeds. The analysis was performed on 4 replications at 25°C for 7 days. The substrate used was sand previously sterilized (8 h at 150°C in a forced circulation oven) and wet with distilled water. The count of seedlings was performed at 5 days and then at 7 days.

2.2 Dry-aeration process

2.2.1 Dry-aeration equipment

The equipment utilized in this study belongs to the Department of Chemical Engineering of UNICEN (Universidad Nacional del Centro de la Provincia de Buenos Aires) with headquarters in Olavarría, which has a data acquisition system for temperature to allow tracking the temperature of the air passing through the bed of grain. The equipment allows to dry a grain bed by changing the temperature and flow of drying air. The equipment contains four trays, of equal size, 16 cm wide, 16 cm long, and 0.5 cm high, whereby it was possible to monitor the moisture content of seed in a thin layer of seeds (individually dried). It also contains four drawers, whose sizes are 5 cm high, 16 cm wide, and 16 cm long, corresponding to each of the trays, as shown in Figure 2. Each tray has a standard-type heat-resistance PT100 sensor, built for converting the heat resistance signal into a standard 420 mA signal for which the transducer is allocated. They were calibrated by manufacturer for a range from 0°C to 200°C.

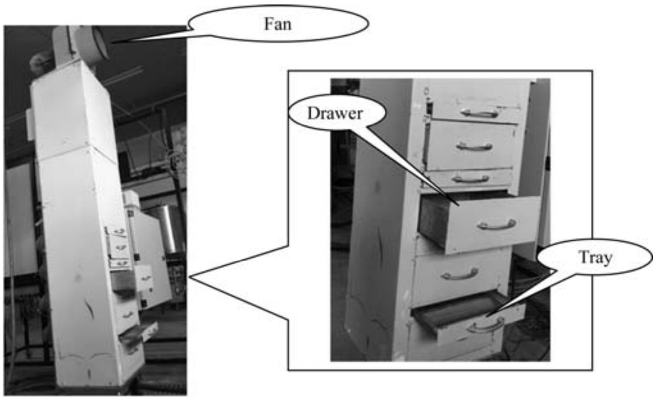


Figure 2 Dry-aeration equipment employed in the studied processes

2.2.2 Experimental drying processes

In this study, four dry-aeration processes and two conventional drying processes were analyzed. Here, were evaluated two drying temperatures and two tempering times. Temperatures and tempering times were those used in the industrial practice. The drying temperature analyzed were 60ºC and 80ºC and the tempering time were 30 and 120 minute. Table 1 shows the analyzed dry-aeration processes (P1 to P4). Samples of 100 g were placed on the equipment trays, and 1300 g samples were arranged in each drawer. The air flow enters the seeds mass perpendicularly from the first to the last tray (from top to bottom), with 0.088 m s^{-1} ± 0.016 average air speed, during all tested drying processes. The drying time of grains was determined by the decrease in weight of the samples contained in each tray. This samples were weighed at one-minute time intervals; moisture content on the dry basis (d.b.) of the four trays was calculated by weight difference, the all heat drying process being finished when the average moisture reached 19% (w w^{-1}) moisture (d.b.) (2.5 points on wet basis moisture above the base marketing or safety storage). Immediately after that, the tempering process is started. Once tempering time for each dry-aeration process is finished, aeration is started to reach the required moisture for soybean marketing (15.6%, d.b.). During the aeration, air flow rate similar to the one implemented during the heat drying step (0.088 m s^{-1}) was used. In duplicate sample processing times equally conditions were respected.

Also, conventional drying process were performed at each tested temperature, 60ºC and 80ºC (P5 and P6 in Table 1). This process involves drying with hot air until reaching the marketing moisture of seeds, followed by aeration with air at room temperature to cool seeds. The seeds were weighed each one-minute interval, and average moisture (d.b.) was computed until marketing moisture was reached.

Table 1 Descriptions of the analyzed drying processes

Process, P	Temperture, ºC	Tempering, min
P1	60	120
P2	60	30
P3	80	120
P4	80	30
P5	80 60	-
P6	60	-

2.3 Results analysis

Statistical analysis of the obtained data was performed using ANOVA (analysis of variance) with SYSTAT software for Windows (Wilkinson, 1990). Also, Tukey technique ($\alpha = 0.05$) was implemented to verify the mean difference between the sample without drying treatment and the dried samples by each of the proposed drying systems.

3 Results and Discussion

3.1 Characterization of soybean seeds

Table 2 displays the results obtained in the characterization of soybean seeds for initial soybean and wetted soybean seeds. These soybean seed samples showed a low break tegument, less than 42% reported in the literature. This indicates a proper postharvest handling of seed, as also a high germination power (Colombo et al. 2006). For wetted soybeans, the increase in moisture content causes the germination decrease by 22%, a result consistent with a study by Bauer et al. (2003). The tegument break was similar for both samples of soybean.

Hereinafter the soybean sample which it is dried by the processes in analysis is the wetted soybean.

Table 2 Results of characterization analysis of soybean seeds

Physical characteristics of initial soybean seeds		
Analysis	Result	Bibliographic value
Apparent density	0.68 ± 0.70 g mL^{-1}	0.732 g ml^{-1} (Kachru, 1994)
Real density	1.22 ± 0.01 g mL	1.19 g mL^{-1} (Kachru, 1994)
Porosity	44.2%	38.8% (Kachru, 1994)
Equivalent diameter	6.56 mm	5.13 mm (Kachru, 1994)
Analysis	Result	
Initial soybean seeds		
Moisture (% w.b.)	10.9 ± 0.28	
Moisture (% d.b.)	12.3 ± 0.36	
Break tegument (%)	11 ± 2	
Germinating power (%)	90 ± 6	
Wetted soybean seeds		
Moisture (% w.b.)	21.4 ± 0.58	
Moisture (% d.b.)	27.2 ± 0.37	
Break tegument (%)	10 ± 2	
Germinating power (%)	74 ± 4	

3.2 Results of Drying processes

Table 3 shows the times of each stage for each drying process. The highest drying times with hot air were obtained for P 5 and P 6 processes, by convetional drying and this occurs because it is necessary to reduce moisture to a safe storage level with hot air. The conventional drying doesn't have tempering. For dry-aeration processes, at the end of the tempering time, air at room temperature was applied to achieve safe moisture storage and cool the seed. These results are influenced by relative humidity of the specific day of drying process. Appendix A shows the humidity conditions for each experimented treatments, where the highest daily relative humidity was observed in process 2.

Table 3 Drying and aeration times in all experiment treatments

Process	Drying time with hot air, min	Aeration time, min
P1	41	26
P2	76	162
P3	44	93
P4	40	84.2
P5	77.5	40
P6	126.4	30

Figure 3 shows the effects of the temperature and on the seed moisture content as a function of processing time for each tray of the equipment in Process 3 (80ºC and 120 min. tempering time). This gives an idea of the behavior of the drying equipment. The seed's moisture decreases acording to processing time. Its reduction was bigger in tray 1 because tray 1 was in direct contact with the hot air entering the equipment. Tray 4 had a smaller moisture reduction because it was further away from the hot air source. A similar behavior was that of the temperature. Tray 1 presented the highest temperature and tray 4 the lowest. The final results are the average results of each of the four trays.

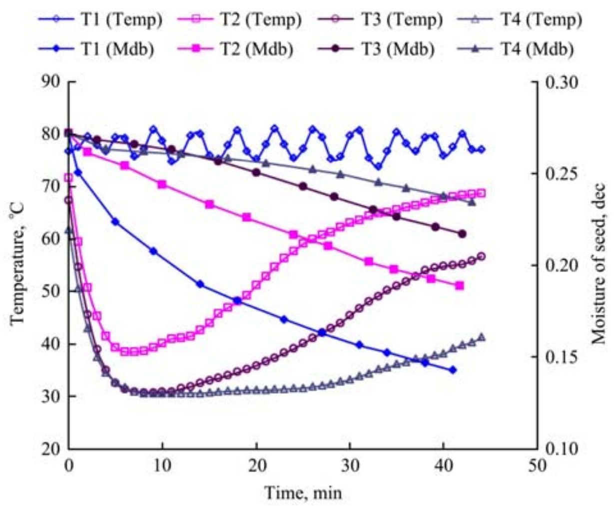


Figure 3 Temperature performance (Temp) and moisture dry base (Mdb) of the seeds for each tray (T) of the equipment in Process 3 (80ºC and 120 min. tempering time) as a funtion of time processing with hot air

3.2.1 Tegument's Break Results

Figure 4 shows the results obtained for tegument breaking analysis of soybean drying in each processes analyzed (P1 to P6) with wetted soybean (WS). The results displayed a strong temperature drying effect on the tegument break in P4 and P5, which had the highest percentages of tegument breaking. Also, the results show a positive effect of tempering time for equal drying temperature (P1, P2 and P6). The highest tempering time (120 min. in P1) caused less damage that less tempering time (30 min. in P2), as well as conventional drying, with no tempering time (P6). Preserve the integrity of the tegument is very important to maintain quality of the seed for long time. In this study case, the process that less damages causes in the tegument was P1, by dry-aeration process at lower temperature and higher tempering time. The tempering time has a positive effect on the preservation of seed integrity (Aquerreta et al., 2007). The ANOVA statistical analysis found significant differences between wetted soybean and drying processes analyzed (p<0.001) (see Table 1B in Appendix B). This was corroborated by analysis of mean differences (Tukey α=0.05), confirming the differences between the samples analyzed (as shown in Figure 4 by different letters).

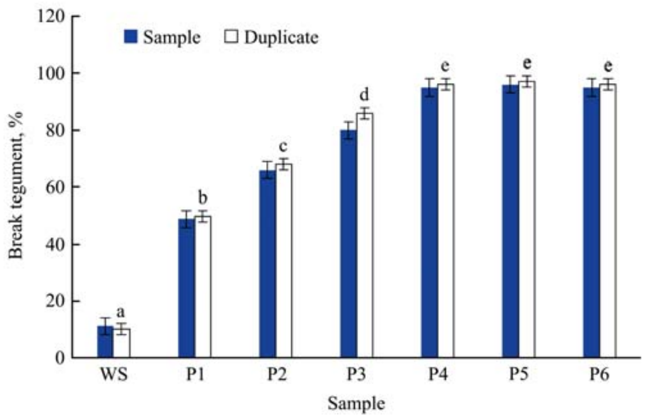


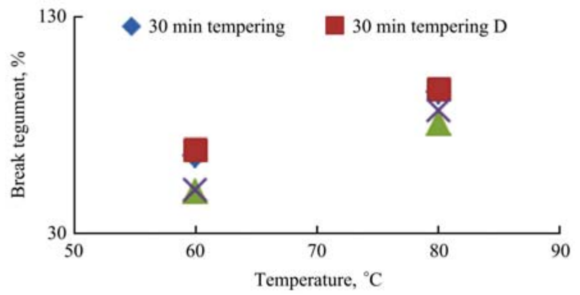
Figure 4 Results obtained for tegument break of soybeand seeds. Different letters indicate significant differences (Tukey's test, α=0.05)

3.2.2 Tegument's Break Results for Dry-aeration processes

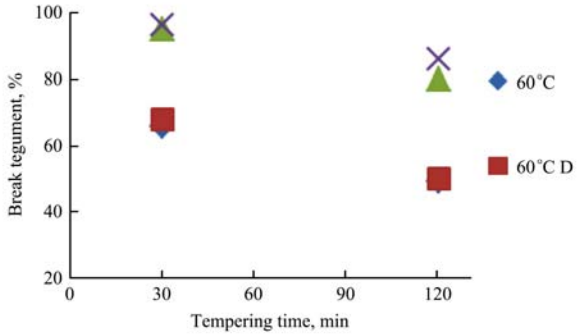
In this work, all dry-aeration processes studied affected the tegument break. Figure 5 shows the effects of temperature (Figure 5a) and tempering time (Figure 5b) on tegument breaking. This figure displayed that higher drying temperature has a negative effect on tegument break at both tempering times (Figure 5a). An increase of tempering time of 90 min. decreases the damage of tegument break; at 60ºC, decreases the damages in 26% and at 80ºC, the damage is reduced by 13% (Figure 5b). The ANOVA statistical analysis found significant differences considering the variables temperature and tempering time (p<0.001) (see Table 2B in Appendix B). There is no significant interaction between the two variables (p>0.198).

3.2.3 Results of the comparison between dry-aeration and conventional drying processes in Tegument Break

Figure 6 analyses the two dry-aeration processes for each tempering time implemented. The highest tempering time has a positive effect on tegument break (Figure 6b) for both temperatures drying compared to convention drying. For 30 min. tempering and temperature of 60ºC damage is less compared with conventional drying; but at 80ºC, damage was similar for both drying processes (Figure 6a). The ANOVA statistical analysis revealed significant differences between the analyzed temperatures (p<0.001). There are significant differences between drying processes (see Table 3B and 4B in Appendix B) and there is significant interaction between the two variables (p<0.001).

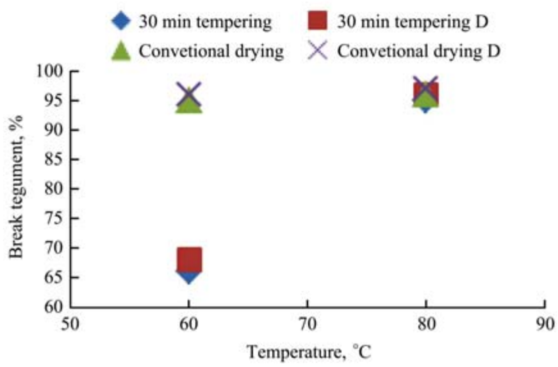


a. Temperature

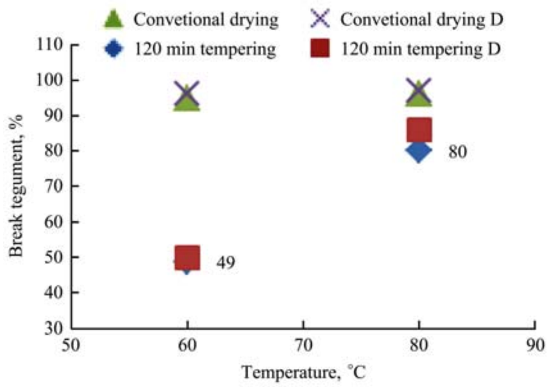


b. Tempering time

Figure 5 Effects of temperature and tempering time in dry-aeration process in soybean seeds. D indicates duplicate.



a. Dry-aeration



b. Conventional drying

Figure 6 Effects of the comparison between Dry-aeration and conventional drying processes in Tegument Break

3.2.4 Results of the Germinating power

Figure 7 shows the results obtained for germinating power in wetted soybean for each of the drying processes analyzed. The results obtained displayed a strong negative effect of conventional drying processes (convective drying) and dry-aeration processes to higher temperature (P3 and P4). Between two drying processes, conventional processes have a major negative effect on germinating power. The ANOVA statistical analysis revealed significant differences between wetted soybean and drying processes in relation to germinating power (p< 0.001) (see Table 5B in Appendix B). This was corroborated by the analysis of mean differences (Tukey α=0.05) where the differences between the samples analyzed are shown in Figure 7 with different letters. There are no differences between WS (wetted soybean) and P1, as there are no significant differences between P3, P4 and P6.

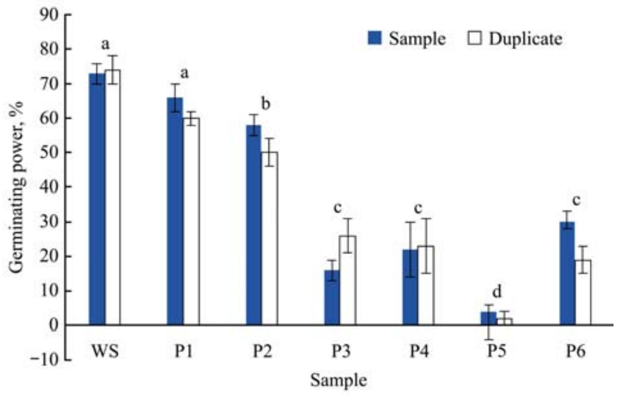


Figure 7 Results obtained for the germinatin power concerning each drying process analyzed and wetted soybean (ws). Different letters indicate significant differences (Tukey's test, α=0.05).

3.3 Germinating power results for Dry-aeration processes

Figure 8 shows the effects of drying temperature (8a) and tempering time (8b) for dry-aeration processes. It is displayed that at higher temperatures drying decreases the germination for both tempering times; for 120 min. tempering, the reduction was 66.7% and for 33 min. tempering, the reduction was 58.3% (Figure 8a). In Figure 8b it can be seen that an increase in tempering time of 30 to 120 min., at 60°C, results in an increase in the germination power (14.3%) while at the highest temperature, 80°C, the opposite effect occurs, with a reduction of 6.7%. These results were corroborated by ANOVA statistical analysis where significant differences between temperatures studied were found (p<0.001) (see Table 6B in Appendix B). There are no significant differences between tempering times (p>0.780) as there are no interactions between both variables (p>0.213).

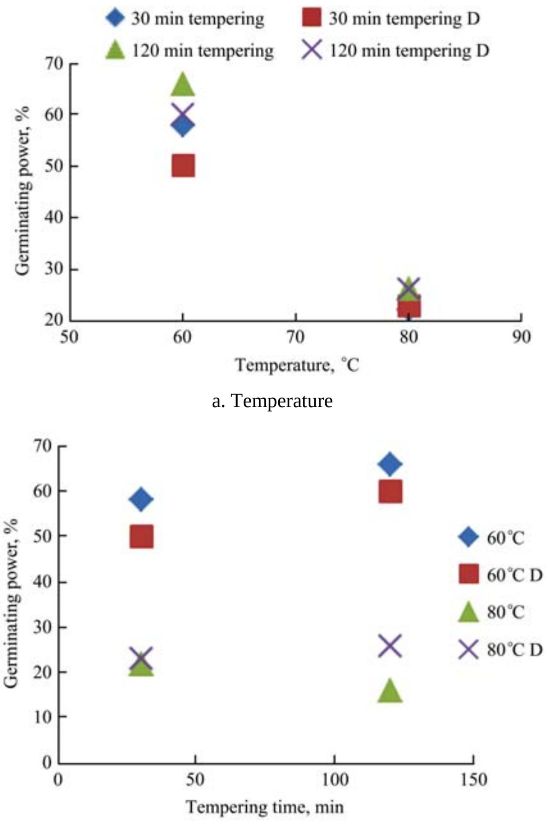
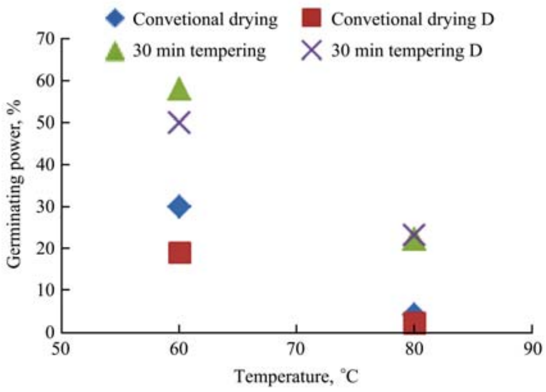


Figure 8 Effect of temperature and tempering time in dry-aeration processes on germinating power of soybean seed

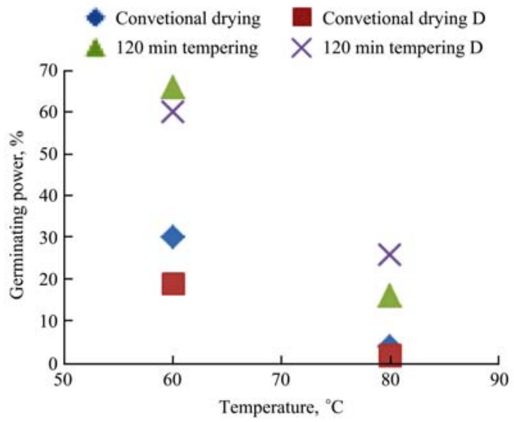
Results of the comparison between Dry-aeration and conventional drying processes in germinating power

Figure 9 shows results obtained comparing the two drying processes: conventional drying and dry-aeration with 30 min tempering (Figure 9a) and conventional drying and dry-aeration with 120 min. tempering (Figure 9b). For both temperatures and both tempering times, the conventional drying generated highest damage. These results were analyzed by ANOVA statistical analysis, revealing significant differences between the analyzed temperatures (p<0.001), as well as significant differences between drying processes (p<0.001). There were no interaction between both factors (P>0.064) (see Table 7A and 8A in Appendix B).

Figure 10 shows the result obtained in germinating power analysis for process P5 (conventional drying at 80ºC). In this case, those *plantulas* (seedlings) had seven days of incubation. The P5 process was the one that generated the greatest decrease of germinating power.



a. Dry-aeration



b. Conventional drying

Figure 9 Effects of Dry-aeration and conventional drying processes in germinating power.

Figure 10 Result of germinating power in conventional drying at high temperature (P5)

4 Conclusion

In this work were analyzed two drying processes about soybean seed quality. The quality variables analyzed were breaking tegument and germinating power and processes analyzed were dry-aeration and conventional drying. In the dry-aeration processes were analyzed two drying temperatures and two tempering times. Furthermore they were analyzed conventional drying processes at each drying temperatures.

The results obtained for tegument break analysis displayed that the conventional drying processes caused more damage. While that dry-aeration process at higher temperature and less tempering time had a similar effect. This shows a marked and strong temperature effect on the integrity of the tegument. The implement of tempering times in dry-aeration processes has the objective to avoid this kind of damage in the seeds. For dry-aeration processes, the process with lower temperature (60°C) and higher tempering time (120 min) caused less damage in tegument seeds.

For germinating power, the results showed that the higher the drying temperature the lower the seed germination for both drying processes. All processes had a negative effect on this analysis. As in the previous variable, the process with lower temperature (60°C) and higher tempering time (120 min) had the highest germination effect. For this drying process, lower temperature had a marked positive effect of tempering time. The higher tempering time did not show positive effects about germination power for the higher drying temperature (process P3).

Appendix A

Table 1A shows the weather conditions for each day of dry processing.

Table 1A Dry bulb temperature (DBT), Humid bulb temperature (HBT), Relative humidity (RH) for each day of process analyzed

Process	Weather conditions		
	DBT, ºC	HBT, ºC	RH, %
P1	22	16	54.4
P1D	20	17	74.9
P2	23	19	69.1
P2D	20	17.5	78.7
P3	22	17	60.9
P3D	20	14	52.4
P4	19.5	13	47.4
P4D	19	13	51.1
P5	20	14	52.8
P5D	22	16	54.7
P6	15	10	54.1
P6D	13	10	69.2

Duplicate (D)

Appendix B

Tables 1B to 4B shows the results obtained by ANOVA analysis for tegument break, considering all the drying processes and wetted sample soybean seeds and their interactions: processes – temperature and processes – tempering time.

Table 1B Results obtained by ANOVA analysis for drying processes and wetted sample soybean seeds

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Processes	12365.857	6	2060.976	641.193
Error	22.500	7	3.214	

Table 2B Results obtained by ANOVA analysis for dry-aeration processes and wetted sample soybean seeds

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Temperature	1922.0	1	1922.0	366.095
Tempering	450.0	1	450.0	85.714
Temperature-tempering	12.5	1	12.5	2.381
Error	21.0	4	5.22	

Table 3B Results obtained by ANOVA analysis between dry-aeration processes and conventional drying for 30 min of tempering

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Process	435.125	1	435.125	497.286
Temperature	435.125	1	435.125	497.286
Process-Temperature	378.125	1	378.125	432.143
Error	3.5	4	0.875	

Table 4B Results obtained of ANOVA analysis between dry-aeration processes and conventional drying for 120 min of tempering.

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Process	1770.125	1	1770.125	363.103
Temperature	595.125	1	595.125	122.077
Process-Temperature	528.125	1	528.125	108.333
Error	19.5	4	4.875	

Tables 5B to 8B shows the results obtained by ANOVA analysis for germinating power considering all the drying processes and wetted sample soybean seeds and their interation: processes – temperature and processes – tempering time.

Table 5B Results obtained by ANOVA analysis for drying processes and wetted sample soybean seeds concerning germinating power

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Processes	8296	6	1382.667	57.783
Error	167.5	7	23.929	

Table 6B Results obtained by ANOVA analysis for dry-aeration processes and wetted sample soybean seed concerning germinating power

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Temperature	1764	1	1764	70.209
Tempering	2.25	1	2.25	0.09
Temperature-tempering	55.125	1	55.125	2.194
Error	100.5	4	25.125	

Table 7B Results obtained by ANOVA analysis between dry-aeration processes and conventional drying for 30 min of tempering concerning germinating power

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Process	1596.125	1	1596.125	48.923
Temperature	2016.125	1	2016.125	61.797
Process-Temperature	210.25	1	210.25	6.441
Error	130.5	4	32.625	

Table 8B Results obtained by ANOVA analysis between dry-aeration processes and conventional drying for 120 min of tempering concerning germinating power

Source of variation	Sum of square	DF	Mean sum of square	*F*-value
Process	1763.675	1	1763.675	1.599
Temperature	155.657	1	155.65725716.693	0.141
Process-Temperature	25716.693	1	1103.314	23.309
Error	4413.255	4		

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Conflicts of Interest: The authors declare no conflict of interest.

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