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Immediate and latent effect of drying air on *Chinese capsicum* seed quality

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Abstract

Pepper is usually propagated by seeds. Therefore, seeds must have high physiological quality along with other factors to ensure strong stabilization of the crop. The Brazilian market for this aromatic plant is predominant in family agriculture. Brazil encounters problems regarding the use of pepper seeds, as there are high losses in the post-harvest phase of the product. In this project, the objective was to evaluate the quality of pepper seeds subjected to drying at temperatures of 30, 35 and 40 °C in different storage periods to minimize the risk of damage to seeds due to inadequate drying. The study was conducted in a completely randomized design with three drying temperatures and seven periods of storage (180 days) with four replicates. The germination test, electrical conductivity, water content, tetrazolium test and field emergence were performed. It was concluded that drying air temperatures of 30, 35 and 40 °C significantly influenced the quality of the seeds. After drying, pepper seeds can be stored for up to 120 days without their quality being affected dramatically.

Keywords: damage, deterioration, pepper, storage, temperature.

Introduction

The pepper plant is shrub, reaching 120 cm in height, with extensive formation of lateral branches and possibility of becoming perennial. Basically, there are two genera of peppers more known, *Piper* and *Capsicum* (Araújo et al., 2014). Peppercorns of the genus *Capsicum* L. are native to America but their exact origin is controversial. Some researchers believe that they are originated in the Amazon Basin, while others claim that they originated in Central America or even in Mexico (Pereira et al., 2014). The Bode pepper (*Capsicum chinense*) presents a high content of capsaicin, also high levels of oxidant used in medicine (Aldana-Iuit, 2015). It has fruits with calyx showing basal constriction between the calyx and the pedicel. It has fruits of various colors and several shapes, usually pendulous, fleshy walls more than 1 mm thick (Araújo et al., 2014). In all cases the water content of the seeds during the harvest is not adequate for the storage, making the accomplishment of the drying process necessary (Abud et al., 2013). Drying is a stage of pre-processing that aims at delaying the deterioration of the seeds during the storage phase. Water stress reduces biological activity and physical and chemical changes occurring during the storage period (Carvalho and Nakagawa, 2012). Therefore, the artificial drying requires knowledge of heating and water loss on the final quality, besides requiring the operational domain related to its yield (Abud et al., 2013). Proper drying allows the conservation of physiological characteristics of seeds during storage, which is very important for the commercialization, planting and consumptions of the products. Furthermore, it allows the anticipation of the harvest avoiding losses of diverse nature during the productive process (Peske et al., 2012). According to Peske et al. (2012), the process of seeds drying for storage allows the preservation of their germination capacity, for which it is necessary to understand the ideal level of humidity and temperature. However, the ideal indices for this process may vary according to the species and the variety of the product stored. It is also necessary to know the physiological behavior of the seeds in the post-harvest period, so that it is possible to develop new methods and equipment for longer conservation and commercialization of these seeds for a longer period, maintaining its final quality (Aldana et al., 2015). The objective of this work was to evaluate the quality of bode pepper seeds after the immediate and latent effect of drying air at temperatures of 30, 35 and 40 °C.

Results and discussion

The drying temperatures did not influence the water content of the seeds at storage periods of 0 and 30 days after drying, while for the drying temperature of 40 °C, the water content of the seeds was reduced during the storage period. In all

temperatures, the highest values of water content were recorded in the period of 120 days after drying (Table 1).
Water contents at 40 °C ranged from 4.85% to 12.18%, at 30 °C the variation was from 8.31 to 12.03%, and at 35 °C the variation was from 6.83 to 13.76%.
Since in this work the seeds were stored in paper packages, the difference in the values of water content during storage and between temperatures can be explained. So the water vapor and the oscillations in the local atmospheric conditions modified the content of seed water during storage, where during the 120-day storage period there was a large amount of rainfall in the region of work (Carvalho and Nakagawa, 2012) causing extra humidity.
Silva et al. (2010), also found a variation in water content in rice, maize and bean seeds during the eight-month period, as a function of the rainy season. Similar variations were also found by Costa et al. (2012) when working with drying temperature and storage periods with crambe seeds (*Crambe abyssinica*) where the values of water contents of the cambre seeds varied from 7 to 15% after drying at 35 °C.

Physiological quality of seeds

Percentage of normal seedlings decreased as a function of the storage period for all temperatures tested. From 150 days, the percentage of normal seedlings reduced until reaching to 0 (Table 2). Analysis of storage time factor showed that the highest germination percentages of pepper seeds are found at 35 °C.
At all drying temperatures within each of the storage periods, there were significant differences ($p<0.05$) between the percentage of germination. From storage time 0 to 120 days, the highest percentages of germination were found at temperatures of 30 and 35 °C but did not differ statistically. The germination averages decrease up to 90 days of storage, rising again in the 120 days of storage, which can be explained by the fact that in that period there is more water available for the seeds to re-germinate (Table 1). After that period, when the water content of the seeds was higher, the values were reduced to 150 and 180 days of storage and the germination values reached to zero.
Lima and Smiderle (2014), worked on pepper seed storage and found that the highest germination (84%) are found in the first months and then the germination may decrease throughout the storage (reaching 11%). Ricci et al. (2013) also verified higher averages for the germination of pepper seeds in the first two months of storage, which means that germination also reduced throughout the storage.

Tetrazolium test

The values of viable seeds presented significant differences ($p<0.05$) only for the first month of storage, where the values for the temperature of 30 and 40 °C were lower than temperature of 35 °C (Table 3). In other months of storage, drying temperatures did not influence viable seed values which were always between 42% and 58%. Regarding the data on storage, it is observed that the values of viable seeds followed a linear trend along the days of storage, neither varying nor having a maximum peak.
According to Lopes (2012), the seeds have the capacity to remain viable throughout the storage period. However, they may not present the necessary vigor to germinate and generate a normal plant. From this work, we concluded that pepper seeds were remained viable throughout the storage, but did not show the vigor to germinate and to make a normal plant.
Gagliardi and Marcos Filho (2011) hydrated two new pepper cultivars and verified that the rate of viable seed was around 84% before the germination test. The same behavior was observed for the second cultivar of pepper which presented 54% of viable seeds before the germination test.

Electrical conductivity

From Table 4, it can be observed that there was a significant difference ($p \leq 0.05$) between drying temperatures from 60 days of storage. Regarding storage days, it is observed that the average values of electrical conductivity tend to increase up to 150 days of storage, where for all drying temperatures there was maximum conductivity and at 180 days of storage the electrical conductivity data drop indicated that the seeds are almost completely deteriorated and do not have as many compounds to lose by leaching into the aqueous medium.
The significant difference between the studied temperatures can be observed from the 60 days of storage, since the highest values of electrical conductivity were recorded at the temperatures of 30 and 40 ° C. At 90 and 120 days of storage, the highest value of electrical conductivity was measured at the temperature of 30 °C. At 150 and 180 days of storage, the highest values of electrical conductivity were observed at temperatures of 30 and 35 °C.
This condition was also observed by Pepper seeds (Vidigal et al., 2009), where the electrical conductivity value of some pepper seed lots ranged from 489.98 to 499.34 µS cm-1g-1.
It can also be observed that up to the 30 days of storage of the pepper seeds, the values of the electrical conductivity did not present significant difference, indicating that the temperature of the drying air did not influence the effect of the amount of leached electrolytes from the seed to the aqueous solution.
From the 60 days of storage, the temperature rise influenced the electrical conductivity of the seeds, ranging from 464.96, 397.94 and 420.25 µS $cm^{-1}g^{-1}$ for temperatures of 30 to 40 °C, respectively.
Abreu et al. (2011) found that the amount of electrolytes leached in seeds of two hybrids of sunflower seeds also increased with the course of the storage period. The same was reported by Ricci et al. (2013) for seeds Jalapenho variety of pepper.
Oliveira (2013) found that the values of conductivity between the two seed lots were increased during the storage period of pepper. He also noticed that the longer the seeds passed inside the aqueous solution the conductivity values were modified further.

Seed emergence

The difference between emergence percentages among drying air temperatures was only observed in the 30 days after storage (Table 5).

Table 1. Water content (% b.u.) of the pepper seeds in the storage periods after drying.

T (°C)	Storage (Days)							R ²
	0	30	60	90	120	150	180	
30(1)	9.50 a	8.31 a	9.35 a	9.02 a	12.03 a	9.56 a	8.42 a	0.67*
35(2)	8.58 a	6.83 a	8.43 a	10.34 a	13.76 a	9.46 a	8.20 a	0.68*
40(3)	7.58 b	4.85 b	7.38 b	10.04 a	12.18 a	9.42 a	8.21 a	0.71*
cv (%)	9.11	1.47	2.15	0.16	10.33	2.53	0.30	

Means followed by the same letters in the column do not differ statistically from one another by the Tukey test (p<0.05). *R² Significant at 5% confidence interval by t-test. (1) y = -0.0834x2 + 0.7256x + 9.193, (2) y = 0.9601x + 7.2869, (3) y = 1.1581x + 5.4079.

Table 2. Percentage of normal seedlings after twinning test of pepper seeds in the storage period after drying.

T (°C)	Storage (Days)							R²
	0	30	60	90	120	150	180	
30(1)	64 a	66 a	48 a	32 a	36 a	0.0 a	0.0 a	0.91*
35(2)	70 a	78 a	50 a	36 a	42 a	2.0 a	2.0 a	0.88*
40(3)	22 b	25 b	18 b	21 b	26 b	2.0 a	2.0 a	0.53*
cv (%)	7.2	9.2	7.8	10.0	5.7	0.0	0.0	

Means followed by the same letters in the column do not differ statistically from each other, by the Tukey test (p<0.05). *R² Significant at 5% confidence interval by t-test. (1)y = -0.4x+71.143, (2)y= -0.4333x + 79, (3)y = -0.11167x + 27.01.

Table 3. Percentage (%) of the tetrazolium test of viable pepper seeds in the storage period after drying.

T (°C)	Storage (Days)							R²
	0	30	60	90	120	150	180	
30(1)	36 b	48 a	58 a	50 a	54 a	54 a	56 a	0.72*
35(2)	46 a	42 a	50 a	48 a	54 a	54 a	48 a	0.50*
40(3)	20 c	54 a	56 a	50 a	58 a	48 a	48 a	0.69*
cv (%)	10.07	6.26	8.98	7.18	8.55	9.45	8.53	

Means followed by the same letters in the column do not differ statistically from each other, by the Tukey test (p<0.05). R*R² Significant at 5% confidence interval by t-test. (1)y = 0.081x + 43.571, (2)y = 0.0405x + 45.214, (3)y = 0.0881x + 39.786.

Table 4. Electrical conductivity of the pepper seeds (µS cm-1 g-1) in the storage period after drying.

T (°C)	Storage (Days)							R²
	0	30	60	90	120	150	180	
30(1)	362.17 a	441.23 a	464.76 a	569.64 a	723.39 a	1062.47a	535.27 a	0.89*
35(2)	357.18 a	404.55 a	397.94 b	420.53 c	622.07 b	1082.37a	559.19 a	0.96*
40(3)	400.52 a	428.54 a	420.25 a	507.86 b	645.42 b	724.15 b	498.60 b	0.94*
cv (%)	14.01	15.05	13.14	27.07	10.07	20.70	14.09	

Means followed by the same letters in the column do not differ statistically from each other, by the Tukey test (p<0.05). *R² Significant at 5% confidence interval by t-test. (1)y = 133.19x + 148.61, (2)y = 119.87x + 162.94, (3)y = 67.142x + 302.53.

Table 5. Percentage of emergence of pepper seeds in the storage period after drying.

T (°C)	Storage (Days)							R²
	0	30	60	90	120	150	180	
30(1)	71.0 a	42 b	56.5 a	57.0 a	70.5 a	65.0 a	64.5 a	0.62*
35(2)	68.5 a	46 a	64.5 a	54.5 a	61.5 a	68.5 a	59.5 a	0.69*
40(3)	67.5 a	51 a	65.0 a	57.5 a	67.0 a	72.5 a	71.5 a	0.61*
cv (%)	4.81	8.21	5.32	6.15	11.25	8.26	7.29	

Means followed by the same letters in the column do not differ statistically from each other, by the Tukey test (p<0.05). *R² Significant at 5% confidence interval by t-test. (1)y = -4.6964x + 68.929, (2)y = -1.25x + 62.75, (3)y = -0.4x + 62.8

Regarding the days of storage, it is observed that the data have a linear tendency. The highest values of emergence percentage were found at 0 days storage for all temperatures, where the pepper seed had the best vigor characteristics. At 120 days of storage it was also observed that emergency percentages rise again. As already verified by Queiroz (2011) the differences of the emergency percentage during the storage can be related to the dormancy of some vegetables, such as pepper, which can last up to three months repeating in cycles (Carneiro et al., 2010) .

Materials and methods

Plant material and place

The seeds of pepper (*Capsicum chinense*) variety Bode were obtained from peppers cultivated in the fruit growing sector of the Federal Goiano Campus Ceres Institute during the whole period of the work. Afterwards, the fruits were transported in plastic bags to the Laboratory of Physiology, Federal Goian Institute - Câmpus Ceres, for the extraction of the seeds that was done manually.

Conduction of experiment

After this process the seeds were deposited in plastic trays in laboratory ambient, without humidity and temperature control, until reaching water content close to 15%. The initial water content of the seeds was determined by the standard oven method, 105 ± 3 ºC, for 24 h, with three replicates of 10 g (Brasil, 2009).
The seeds were dried at three temperatures, 30, 35 and 40 °C in forced ventilation greenhouses with 35, 28 and 22% relative humidity, respectively, and were then stored in paper bags under ambient conditions for seven months.

Physiological seed quality tests

Evaluation of the quality of pepper seeds submitted to drying air was performed by the following parameters: water content, germination test, electrical conductivity, emergency and tetrazolium test.
Germination test was conducted in gerbox plastic boxes, with four replicates of 50 seeds per treatment, distributed over three sheets of germiteste paper, moistened with 2.5 times the weight of the dry substrate. The cells were maintained in BOD-type germinators under alternating light regime (16-h in the dark and 8-h in the presence of light) and the temperature used was 25 °C (Queiroz et al., 2011). The counts were performed on the 7th and 14th days after the beginning of the test, evaluating the percentage of normal seedlings.
Electrical conductivity test was performed according to the methodology used by Vidigal et al. (2009), by which four samples of 50 seeds with known masses were immersed in 25 mL of distilled water and kept in a BOD incubator at 25 °C for 24 h. After this period, the electrical conductivity of each solution was determined by a conductivity meter, and the results expressed in $\mu S\ cm^{-1}g^{-1}$ of seeds.
For seed emergence testing, four replicates of 50 seeds per batch, individually sown in multicellular trays of polystyrene with separate cells containing commercial substrate. The trays were kept between 25 and 30 ºC, in an oven equipped with intermittent misting system. The evaluations were performed during the 21 days after sowing, by counting emerged seedlings with a size equal to or greater than 1.0 cm (Torres, 2005).
In the tetrazolium test, 50 pepper seeds (*Capsicum chinense* Bode var.) were sown between germiteste paper, previously moistened with water equivalent to 2.5 times the mass of the dry paper and later placed and kept in the germinator in the period of 16 hrs at 25 °C. After this period the seeds were placed in 0.075% solution of 2,3,5-triphenyltetrazolium chloride for three hours in dark at 45 °C according to Krzyzanowski et al. (1999) to react with the saline solution. After this period, seeds were evaluated. The examination was performed with the help of the stereoscopic microscope. The evaluation criterion was in accordance with the recommendations of Gagliard and Marcos Filho (2011). The seeds were classified as viable and non-viable. The viable seeds were those that showed red coloration, whereas the non-viable seeds presented partially or without red staining of the embryonic tissues.

Statistical analysis

The statistical analyzes were performed in the 3x7 factorial scheme with four replications, where three temperatures and seven the storage periods were imposed. The data were interpreted by analysis of variance by the F test at the 5% probability level, by comparison of means by the Tukey's test (p<0.05) for the temperature factor (qualitative) and regression for the months of storage (quantitative) with the help of the Sisvar program (Ferreira, 2014).

Conclusion

The temperatures of 30, 35 and 40 °C of drying air influenced the quality of pepper seeds (*Capsicum chinense*) variety Bode soon after pre-processing. The storage time of up to 180 days after the drying process caused in quality of Bode pepper seeds. Pepper seeds can be stored for up to 120 days without their quality being affected dramatically. The temperature of 40 °C was the one that most affected seed quality in most of the tests.

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