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Influence of different storage conditions on soybean grain quality

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Abstract

The main qualitative changes on soybean grains during storage were assessed in the present work. The soybean grains were harvested with moisture content around 18 % and dried until 11.2, 12.8 and 14.8 % moisture content. The grains were subsequently stored at the following conditions of temperature and relative humidity for 11.2 % m.c.: 20 ºC and 61.7 %; 30 ºC and 67.9 %; 40 ºC and 69.4 %; for 12.8 % m.c.: 20 ºC and 73.7 %, 30 ºC and 76.7 % and 40 ºC and 80.8 %; and for grains with 14.8 % m.c.: 20 ºC and 82.7 %, 30 ºC and 83.9 % and 40 ºC and 85.3 %. Sampling was carried out every 45 days until 180 days of storage. The following analyses were carried out: moisture content, germination, electrical conductivity and grain classification. The soybean grains generally deteriorated with storage and deterioration was particularly strong for grains stored with initial moisture contents of 12.8 and 14.8 % at 40 ºC. The grains stored with initial moisture contents of 14.8 % at 30 and 40 ºC were classified as out of market standard after 135 and 90 days respectively. Only grains stored with initial moisture contents of 11.2 % at 20 and 30 ºC and 12.8 % at 20 ºC showed satisfactory qualitative characteristics throughout the 180 days of storage.

Key words: Soybean, deterioration, storage conditions, storage quality.

Introduction

Grain quality is an important parameter for marketing and processing, and can affect the commodity value. In spite of all the technology available to Brazilian agriculture, the qualitative and quantitative losses originating during the post harvest process are still not well controlled and , the grain is constantly submitted to external factors during storage. These factors can be physical, such as temperature and humidity; chemical, such as oxygen supply; and biological, such as bacteria, fungal, insects and rodents (Brooker et al., 1992). According to Villa and Roa (1979), the parameters temperature, moisture content, length of storage and percentage of broken grains are all factors that can accelerate or delay the process of deterioration.

Safe storage keeps the qualitative and quantitative aspects of the grains by providing unfavorable conditions for the development of insects, rodents and microorganisms (Bailey, 1974). The storage of grains in the natural environment of tropical areas presents larger problems due to the temperature conditions and relative humidity, when compared to the areas having a cold or temperate climate (Abba and Lovato, 1999). The parameters of temperature and relative humidity during storage are decisive in the process of loss of seed viability and alterations in the grain color and composition (Whigham and Minor, 1978, Liu, 1997, Lacerda et al., 2003). In tropical areas, such as Brazil, where ambient

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temperatures of storage are observed above 20 ºC, the decrease in germination is more accentuated (Dhingra et al., 2001).

Based on this, the object of this study is to evaluate the qualitative alterations to soybean grains stored in different combinations of moisture content and temperature.

Materials and methods

Soybean (*Glicine max* (L.) MERRIL) were obtained from the district of Almeida Campos, Ponte Nova county, MG, Brazil. Grains, with approximately 18 % m.c.(w.b.) at harvest were dried in a fixed bed dryer with natural air to 11.2, 12.8 and 14.8 % m.c. (w.b.). After drying, the grains were stored in plastic containers of about 3.0 L and taken to BOD incubators at 20, 30 and 40 ºC. To guarantee the same grain water content during storage at different temperatures, the equilibrium relative humidity (ERH), previously calculated by the Chung-Pfost model (Navarro and Noyes, 2001) for each combination of temperature and water content (Table 1), was controlled inside each BOD. The data acquisition monitoring was performed by a *1-wire™* system (Martins et al., 2004).

Table 1. Equilibrium relative humidity (ERH) for each combination of moisture content and temperature.

	Moisture content (%)		
Temp. (ºC)	11,2	12,8	14,8
20	61.0	72.0	80.0
30	67.0	76.0	83.0
40	71.0	80.0	86.0

Stored for 180 days, the grains were analyzed every 45 days for the following parameters: moisture content, classification, germination and electrical conductivity. The moisture content was determined using the method S352.2 following the ASAE recommendations (ASAE, 2000). Classification of the grains for commercial purpose was made in agreement with the guidelines from the Brazilian Ministry of Agriculture (MAPA, 1983). The percentage of germination was obtained in agreement with the Brazilian Rules for Analysis of Seeds (MAPA, 1992). The electric conductivity of the solution containing the soybean was made by using a "glass system" or "mass conductivity" (Vieira et al., 2001), used for the purpose of evaluating the increase in the membrane permeability as the grain deteriorates. The experiment was arranged in completely randomized split-plots, with three replicates. The treatments, temperature combinations (20, 30 and 40 ºC) and moisture content (11.2, 12.8 and 14.8 %) were allocated in the main plot, whereas the subplot consisted of the storage periods (0, 45, 90, 135, 180 days), with the treatments arranged in a 3 × 3 × 5 factorial design. Initially, a repeated measures analysis of variance was carried out to determine the best residual covariance structure. Regression analysis was performed for the variable electrical conductivity.

Results and discussion

Moisture content

Table 2 shows the values of the equilibrium moisture content of the soybean stored for 180 days for each combination of temperature and equilibrium relative humidity (E.R.H.). In general, the moisture content of the soybean remained practically constant, with a maximum standard deviation of 0.4, except for the grains stored with 14.8 % m.c. at 30 °C (83 % E.R.H.), and 12.8 and 14.8 % m.c. at the temperature of 40 ºC (80 and 86 % E.R.H., respectively). The increase in moisture content is due to both the grain respiration and to the microflora associated with in, although the grain respiratory rate is usually not as intense as the microorganisms (Pomeranz, 1974, Muir and White, 2000). Still in accordance to these authors, the grain transpiration is higher due to its higher moisture content, although the temperature, the relative humidity and the storage conditions can also influence the grain metabolism.

Classification of the grains

Table 3 shows the average percentages of the sour and damaged soybean stored with moisture contents of 11.2, 12.8 and 14.8 %, in the temperatures of 20, 30 and 40 ºC, whose values were obtained from the official classification requirements issued by the Agricultural Institute of Minas Gerais.In general, the soybean kept the basic standard, except for grains stored with 14.8 % m.c. and temperature above 30 ºC. Although it is possible to verify an increase of the percentage of sour grains and, consequently, of the total of damaged grains, when the grains were stored with 14.8 % m.c. at 30 ºC, for 90 days, the soybean kept the basic standard up to 180 days of storage. However, the grains stored with 12.8 and 14.8 % m.c. at 40 ºC were considered to be out of the basic standard for 135 and 90 days, respectively. In accordance to Brazilian Ministry of Agriculture (MAPA, 1983) the maximum limit of damaged soybean for the basic standard is 8 %.

Table 2. Moisture content of soybean stored for 180 days for each combination of temperature and equilibrium relative humidity

Temp.	EHR	Storage Period (Days)					Average ±
(ºC)	(%)	0	45	90	135	180	sd
	61.0	11.2	11.2	10.8	10.7	10.6	10.9 ± 0.3
20	72.0	12.8	12.6	12.8	13.2	12.9	12.9 ± 0.2
	80.0	14.8	15.0	15.6	14.8	14.7	15.0 ± 0.4
	67.0	11.2	11.3	11.1	10.5	10.6	10.9 ± 0.4
30	76.0	12.8	12.6	12.8	12.8	12.8	12.7 ± 0.1
	83.0	14.8	15.2	16.3	17.9	17.3	16.3 ± 1.4
	71.0	11.2	11.4	11.1	10.9	10.9	11.1 ± 0.2
40	80.0	12.8	13.3	13.5	15.0	14.8	13.9 ± 0.9
	86.0	14.8	15.0	17.6	17.0	16.2	16.1 ± 1.2

Tabela 3. Sour and damaged grains of soybean stored at temperatures of 20, 30 and 40 ºC and moisture content of 11.2, 12.8 and 14.8 % for 180 days.

	Moisture	Storage Period (Days)														
Temp.	content	0			45			90			135			180		
(ºC)	(%)	SR	DMG	CLS	SR	DMG	CLS	SR	DMG	CLS	SR	DMG	CLS	SR	DMG	CLS
	11,2	0.5	1.5	BS	0.2	0.9	BS	0.3	1.4	BS	0.3	1.3	BS	0.3	0.5	BS
20	12,8	0.5	2.2	BS	0.2	0.7	BS	0.3	0.7	BS	0.2	0.5	BS	0.3	0.9	BS
	14,8	0.3	1.6	BS	0.3	1.2	BS	0.4	1.2	BS	0.2	0.8	BS	0.4	0.9	BS
	11,2	0.8	1.7	BS	0.2	0.9	BS	0.4	1.1	BS	0.2	0.5	BS	0.3	0.4	BS
30	12,8	0.7	1.1	BS	0.3	1.1	BS	0.3	1.1	BS	0.4	0.6	BS	0.3	0.4	BS
	14,8	0.8	1.2	BS	0.4	1.2	BS	1.9	4.2	BS	1.3	2.5	BS	2.5	3.6	BS
	11,2	0.2	1.5	BS	0.2	0.9	BS	0.6	1.8	BS	0.2	0.7	BS	0.5	0.8	BS
40	12,8	0.5	1.2	BS	0.3	1.1	BS	0.5	0.9	BS	5.5	8.1[1]	ABS	5.6	8.4[1]	ABS
	14,8	0.8	1.3	BS	0.4	1.4	BS	5.8	8.6[1]	ABS	8.8	11.7[1]	ABS	9.1	14.3[1]	ABS

SR – values of sour grains (%); DMG – values of damaged grains (%); CLS – classification of the soybean; BS – damaged grains inside of the limit for Basic Standard; ABS – damaged grains above the limit for Basic Standard.

[1] Product classified as Out of the Basic Pattern for commercialization for exceeding the maximum limit of damaged grains (8%) established for Brasil (MAPA, 1983).

Germination

In accordance to the results of the analysis of variance ($p < 0.05$), there was a significant difference in the percentage of germination due to the triple interaction between moisture content, temperature and storage period.

The average percentage values of germination of soybean stored with different moisture contents at each temperature during the storage are shown in Figure 1. In general, decresed germination occurred during the storage, regardless of moisture content and temperature.

At the temperature of 20 ºC (Figure 1A), the reduction of the germination potential was more accentuated when the soybean grains were stored with moisture content of 14.8 %. From 135 days of storage the grains did not germinate. However in the temperatures of 30 and 40 ºC (Figure 1B-C), the reduction of germination potential took place independently of the moisture content. It is clear, however, that the reduction was more accentuated as the moisture content of the grains increased. Similar results were obtained by Dorworth and Christensen (1968) when they stored soybean with four moisture contents and at four temperatures, even though they had not controlled the relative humidity during the storage. According to Burris (1980), the fast deterioration of the soybean during the period of storage is influenced by the moisture content and temperature. The qualitative deterioration of soybean stored with initial moisture contents between 9.8 and 13.8% in tropical conditions (30 ºC and 82 % R.H.) was simulated by Locher and Bucheli (1998). These authors verified a more pronounced reduction in the percentage of germination between 5 and 9 months of storage, and this was more accentuated in grains with a higher initial moisture content. The effect of the temperature and relative humidity in the maize viability was studied by Abba and Lovato (1999), who stored seeds with water content of 10.5 % in a temperature of 30 ºC and 95 % of relative humidity. They verified loss of the germinative capacity in the maize after 42 days storage. Bhattacharya and Raha (2002) studied the alterations of soybean and corn stored with moisture contents of 14.0 and 9.7 %, respectively, in the presence of different species of

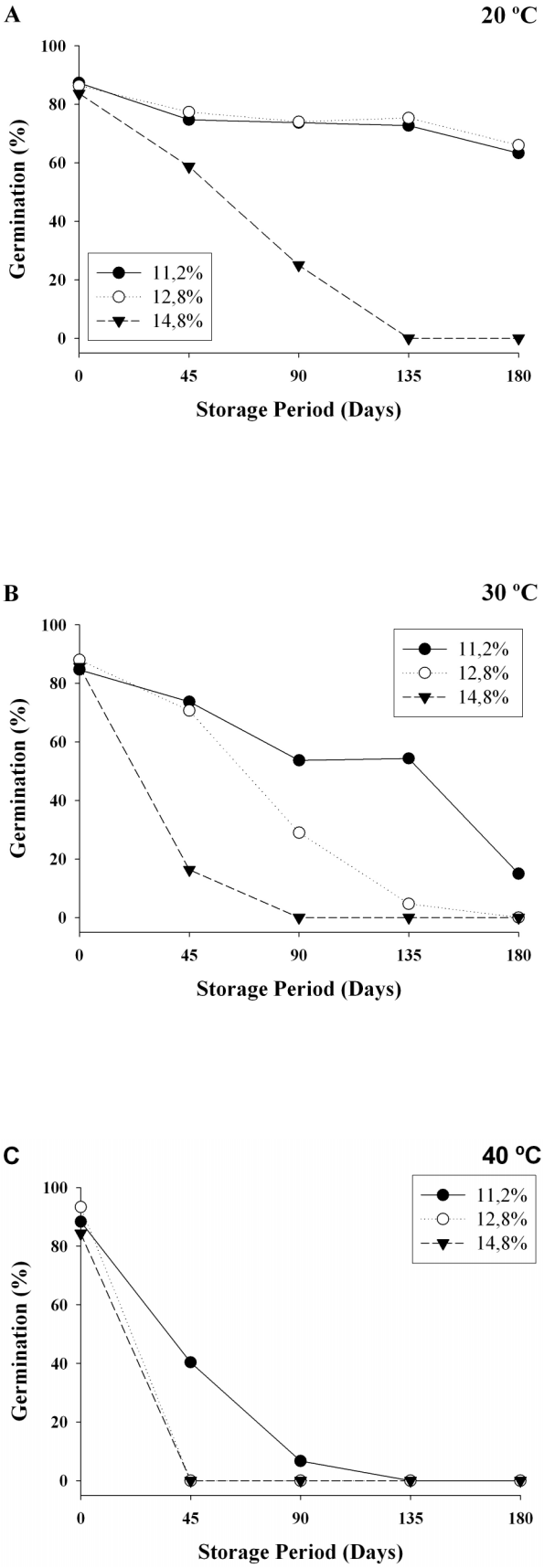

Figure 1. Germination of soybean stored for 180 days for each combination of moisture content and temperature.

storage fungus. These authors observed a decrease in the percentage of germination in the soy and in the maize during the storage period. The percentage of germination in the soybean and corn after 10 and 12 months was zero and 4 %, respectively.

Electric conductivity

The analysis of variance ($p < 0.05$) indicated that there was significant variation of electrical conductivity of the solution that contained the soybean due to the interaction moisture content-temperature-storage period.

Figure 2 shows the regression curves of electrical conductivity, corresponding to the solutions that contained the grains stored with moisture content equaling 11.2, 12.8 and 14.8 %, stored in the temperatures of 20, 30 and 40 ºC. It can be seen that only the grains stored at a temperature of 20 ºC (Figure 2A) and a water content of 14,8 % show an increase of the electrical conductivity and consequent reduction of their physiological quality. In Table 4 the adjusted regression equations and their determination coefficients are shown, which link the electrical conductivity of the solution that contained the soybean grains with three amounts of water and the storage period for each temperature.

In agreement with Heslehurst (1988), readings taken of the electrical conductivity of the solution that contains the grains can be used to evaluate their vigor, because the conductivity is related with the amount of ions leached into the solution, which in turn is directly associated with the integrity of the cellular membranes; badly structured membranes and damaged cells are usually associated with the process of seed deterioration and reduced vigor. The loss of germination and vigor of old seeds is positively correlated with the electrolytic leaching, which increases with the decrease of the phopholipid content of the membrane (Lin, 1990). The smallest values, corresponding to the smallest exudates liberation, indicate high physiological potential (larger vigor), which indicates a smaller disorder intensity in the cell membrane systems (Vieira et al., 2002).

The increase of electrical conductivity was more expressive as the temperature and moisture content

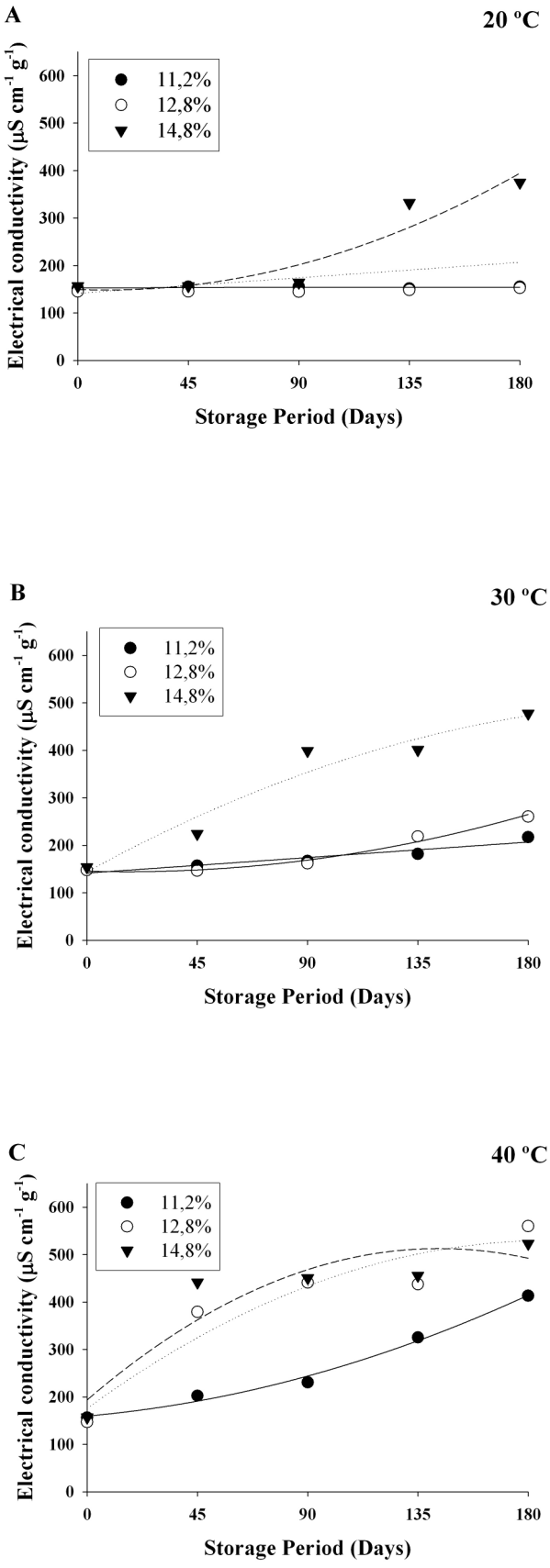

Figure 2. Electrical conductivity of soybean as function of time of storage for each combination of moisture content and temperature.

Table 4. Equations for electrical conductivity as function of time of storage for each combination of moisture content and temperature and respective determination coefficients.

Temp. (ºC)	Moisture content (%)	Equations	r^2	F	Prob.
	11.2	$\hat{y} = 153.4$		0.23	0.6366
20	12.8	$\hat{y} = 147.1$		2.48	0.1389
	14.8	$\hat{y} = 149.4 - 0.203X + 0.009X^2$	0.89	45.54	<0.0001
	11.2	$\hat{y} = 145.4 - 0.040X$	0.91	11.19	<0.001
30	12.8	$\hat{y} = 145.5 - 0.148 + 0.005X^2$	0.87	40.01	<0.0001
	14.8	$\hat{y} = 143.7 + 2.8366X - 0.006X^2$	0.94	91.61	<0.0001
	11.2	$\hat{y} = 159.6 - 0.4586X + 0.0056X^2$	0.97	199.31	<0.0001
40	12.8	$\hat{y} = 175.5 + 3.768X - 1.002X^2$	0.88	45.45	<0.0001
	14.8	$\hat{y} = 194.2 + 4.403X - 1.530X^2$	0.84	31.67	<0.0001

of the grains increased (Figure 2B-C). Those stored at 40 ºC (Figure 2C) showed increased electrical conductivity readings in the solution that contained those grains during the storage period, regardless of the grain moisture content. The electrical conductivity was used by Krittigamas et al. (2001) as parameter in the determination of vigor in stored soybean. The authors observed a significant increase of this parameter and consequent loss of vigor in the grains after 180 days. Krishnan et al. (2004) studied the characteristic thermodynamics of the soy during storage under conditions of accelerated aging and also verified larger medium values of electrical conductivity in the solution that contained the grains as higher temperatures were used during the storage period.

The analysis and the interpretation of the results obtained relating to the grains allowed the following conclusions:

- For final certification, soybean storage is not recommended in the following combinations of moisture content and temperature: 11.2 % at 40 ºC; 12.8% at 30 and 40 ºC; and 14.8 % at 20, 30 and 40 ºC.
- For soybean commercialization at the basic standard level, it is possible to store grains for 180 days with moisture content of up to 14.8 % 20 and 30 ºC. At 40 ºC, only the grains with moisture content of 11,2 % can be stored for 180 days. Grains with water volumes of 12.8 and 14.8 % at 40 ºC can be stored for 135 and 90 days, respectively.

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