ISSN 2175-6813

Revista Engenharia na Agricultura

Viçosa, MG, DEA/UFV - DOI: 10.13083/reveng.v29i1.9939 V.29, p.1-11, 2021

QUALITY OF SOY BEAN GRAIN STORED IN BAG SILO

Vinicius Duarte Pinto[1], Lucas Mingotti Dias[2], Renata Henrique Hoscher[3], Fabiano Rodrigo Gomes[4], Marcelo Alvares de Oliveira[5] & Vanderleia Schoeninger[6]

1 - Agriculture Engineer, Federal University of Grande Dourados (UFGD), viniciuusduarte@gmail.com
2 - Agriculture Engineer, Federal University of Grande Dourados (UFGD), lucasmingotti@hotmail.com
3 - Master Science degree in Agriculture Engineer, Federal University of Grande Dourados (UFGD), renatahoscher@hotmail.com
4 - Technologist in System Analysis and Development, Educational Union of Cascavel, UNIVEL, fabianorodrigogomes@gmail.com
5 - PhD in Agronomy, Researcher at Brazilian Agriculture Research Agency (Embrapa Soja), Londrina/PR, marceloalvares.oliveira@embrapa.com;
6 - PhD in Agriculture Engineer, Professor at Federal University of Grande Dourados (UFGD), vschoeninger@ufgd.edu.br

Keywords:
Glycine max
Hermetic storage
Lipid
Modified atmosphere
Protein

ABSTRACT

Because of the rise in the use of bag silo in the last harvests due to the lack of static capacity in Brazil, the storage of grain in type of structure is currently seen as a solution to our storage deficit. Thus, the importance of maintaining the quality of grains for commercialization in these systems is considered. The objective of this experiment was to evaluate the quality of soybean grain stored in a silo bag, in the region of Dourados, State of Mato Grosso do Sul, Brazilian Central-West. The experiment was carried out in a cooperative, where soybean grain stored in silo bag are collected. The product had been received, processed at the end of the summer harvest and previously stored in metallic silos, and then transferred to the silo bags upon reception of the winter harvest. Thus, soybeans with an average water content of 11% w.b. were packed in bags composed of high-density polyethylene and hermetically sealed over a total period of 125 days, with collections of data on temperature and air relative humidity and grain sampling every 40 days. The collected samples were subjected to plant classification and analyses of water content, water activity, protein, lipids and color parameters were also performed. Na average rise of 5° C was observed in the temperature and 14% for air relative humidity which resulted in the of moldy and fermented grains after 125 days in the bags. The storage period factor was significant ($p < 0.05$) in the variables of water content, color and oil. It was concluded that for soybeans the storage period in hermetic bags influences the quality of the grains and the internal environmental conditions in these structures are influenced by the convective microcurrents observed in the different positions inside the silo bag.

Palavras-chave:
Glycine max;
Atmosfera modificada
Armazenamento hermético
Proteína
Lípideos

QUALIDADE DE GRÃOS DE SOJA ARMAZENADOS EM SILOS BOLSA

RESUMO

Com o aumento no uso de silos bolsas nas últimas safras, dada a falta de capacidade estática em nosso país, o armazenamento de grãos neste tipo de estrutura é visto atualmente como uma solução para nosso déficit de armazenagem. Dessa forma considera-se a importância de manter a qualidade dos grãos para comercialização nestes sistemas. O objetivo para a pesquisa foi avaliar qualidade dos grãos de soja armazenada em silo bolsa, na região de Dourados-MS, Centro-Oeste do Brasil. O experimento foi realizado em uma Cooperativa, na qual realizam-se coletas de grãos de soja armazenados em silos bolsas. O produto havia sido recebido, processado ao final da safra de verão e armazenado em silos metálicos previamente, sendo transferido para as bolsas no momento do recebimento da safra de inverno. Para isso, foram acondicionados grãos de soja com teor de água médio de 11% b.u em bolsas compostas por polietileno de alta densidade e seladas hermeticamente ao longo de um período de 125 dias, sendo realizadas coletas de dados de temperatura e umidade relativa do ar dentro da bolsa e amostragem de produto a cada 40 dias. Amostras coletadas foram submetidas a classificação vegetal e análises de teor de água, atividade de água, proteína, lipídeos e parâmetros de cor. Observou-se aumento médio de 5°C na temperatura, e na umidade relativa do ar de 14%, proporcionando dentro das bolsas aparecimento de grãos mofados e fermentados após 125 dias. O fator tempo de armazenagem foi significativo ($p<0,05$) nas variáveis teor de água, cor e óleo. Concluiu-se que o tempo de armazenamento em bolsas herméticas influencia na qualidade dos grãos e que as condições ambientais internas nestas estruturas são influenciadas pelas microcorrentes convectivas observadas nas diferentes posições dentro da bolsa.

Recebido para publicação em 05/04/2020 • Aprovado em 22/12/2020 • Publicado em 03/03/2021

SECTION EDITOR IN CHARGE
Renata Cássia Campos

INTRODUCTION

A continuous growth has been observed in the last years in the Brazilian grain sector where soybean is the major crop in terms of planting extension and production volume, representing around 50.65% of the domestic production in the 2019/2020 harvest, making the country the second largest world producer, inserted in the economic context as the leading agricultural product (CONAB, 2020). As a consequence, the grains need to be stored; however, the growth in the field has not been monitored by the statistic storage capacity.

To meet this demand in storage, bag-type silo structures also known as bag silos are the technologies that have been spreading in all grain producing regions in Brazil as it is considered a form of temporary emergency airtight storage (CARPANETO *et al*., 2016).

The bag-silo is made of high-density polyethylene in three layers: two black inner layers and a white outer layer of titanium dioxide (FARONI *et al*., 2009). This system prevents the gas exchange between the inner and outer part of the container where the grains are stored, so that the oxygen level inside the bag drops dramatically due to the respiratory processes of grains, microorganisms and insects. Thus, the level of carbon dioxide in the bag increases and, consequently, the development of insects, microorganisms and metabolic activity of the grains is suppressed, benefiting the conservation of the product (FREITAS *et al*., 2016; BARRETO *et al*., 2017; TAHER *et al*., 2019).

This technology was developed for countries with low temperatures most of the year, for example, Argentina and Canada. Therefore, in Brazil, with a tropical climate and high temperatures, there is a high probability of losses or qualitative changes in the grains, as these conditions promote the development of pests and microorganisms as well as na increment in the metabolic activity of the grain, causing hot spots. Unlike the bulk warehouse structures where the existence of well-managed thermometry and aeration system minimizes the loss of the quality and technical breakage in the bag silo structures, there is no use of such storage process control tools. This can be a problem as the heating and humidity spots in the grain mass cannot be identified. Because of this, the storage system in bag silo is restricted as to oficial use, since the legislation imposes the use of thermometry and aeration systems (BRASIL, 2011).

In addition, after harvesting the grains are susceptible to changes in thier physical-chemical, technological and nutritional properties, Where the major parameters affecting the quality of soybean grain during storage include the moisture content of the grains, storage temperature, relative humidity and storage period (KONG; CHANG, 2013). Based on that and considering the importance of maintain the quality of the grains for commercialization and the bag silo as a possible temporary solution for the storage deficit, the objective of this work was to measure the variables temperature and relative humidity and the effect of the storage period on the quality of soybeans stored in silo bags in the Southern region of the State of Mato Grosso do Sul.

MATERIAL AND METHODS

The experiment was carried out at the Grain Storage Unit owned by company Copasul (Sul Matogrossense Agriculture Cooperative), located in the municipality of Dourados, State of Mato Grosso do Sul (MS). Three storage bags with a capacity of 3,000 bags each, with 2.70 m in diameter and 60 m in length each and approximately 180 tons of capacity were randomly selected in the unit. In the storage bags, soybean grain harvested in the 2016/17 summer crop were placed for approximately 125 days. The soybean grain was dried with water content close to 11%, processed and previously stored for five months, in a metallic silos system (equipped with aeration and thermometry). The bags were filled with an embedding machine in the first half of July where the first sampling was performed immediately, and the others after 40, 100 and 125 days of storage.

The data collection consisted of the in loco acquisition of the temperature and air relative humidity data of the intergranular air inside the storage bags. Punctures were made at three points along the length, the first at about 5 meters from the right side, the second at the center of the bag and the third at 5 meters from the left side at 1 meter high. The punctures allowed the entry of a stem set with temperature and relative humidity sensors, connected to a data collection system that enabled the checking of the information at three different heights of the bag silo: at the base, in the center and at the top (Figure 1).

At the points where the data were collected, samples of soybean were collected using a manual pressurizer, reduced to 1 kg each with the aid of a divider also at the three heights of the grain mass: in the lower region, in the center and in the region closest to the surface (top of the bag). After removing the samples, the bags were sealed using a thermal blanket and adhesive tape, and the material collected placed in a thermal packaging was sent to the Laboratory of Physical Properties of Agricultural Products at the Faculty of Agricultural Sciences, Federal University of Grande Dourados - UFGD, Dourados / MS. In the laboratory, some of work sample was separated and sent to the Post-harvest Laboratory of the Technological Seeds and Grains Center "Dr. Nilton Pereira da Costa" of Soybean Embrapa in Londrina, Paraná State.

The plant classification was based on Normative Instruction 11/2007, of the Ministry of Agriculture, Livestock and Supply (MAPA). The group was framed according to the tolerance limits of each variable, depending on its quality (Tables 1 and 2). Group 1 is intended for fresh consumption and group 2 is intended for other uses (MAPA, 2007).

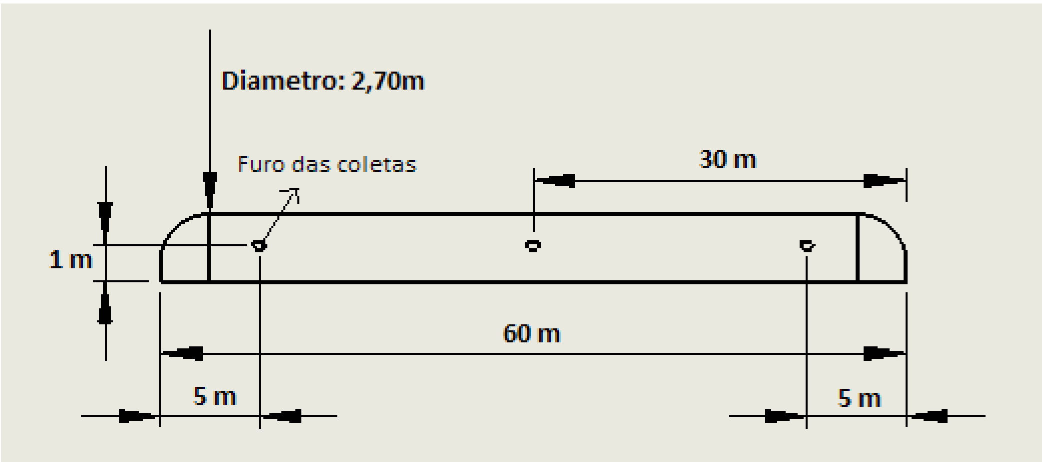

Figure 1. Layout of the data collection points in the bag silo structures

Table 1. Maximum tolerance thresholds, expressed in percentage for Group-1 soybean

Type	Defective				Greenish	Broken, Cracked and smashed	Foreign material and impurity
	Blazed and burned	Maximum of burned	Moldy	Total			
1	1.0	0.3	0.5	4.0	2.0	8.0	1.0
2	2.0	1.0	1.5	6.0	4.0	15.0	1.0

Source: Normative instruction no. 11/2007 – Mapa (2007)

Table 2. Maximum tolerance thresholds, expressed in percentage for Group-2 soybean

Type	Defective				Greenish	Broke, Cracked and smashed	Foreign matter and impurity
	Blazed and burned total	Burned maximum	Moldy	Total			
1	4.0	1.0	6.0	8.0	8.0	30.0	1.0

Source: Normative instruction no. 11/2007 – Mapa (2007)

The water content was determined using the Standard Greenhouse Method (BRASIL, 2009) by storing nine samples from each bag, three from each collection point, with 10g of soybean in a non-corrosive metal container, which were added in forced air circulation oven at 105 ± 1ºC for 24 hours.

To quantify the protein content and oil content, samples with whole grains were used and the Near Infrared Reflectance (NIR) technique was used. The whole and clean grains of each sample were subjected to readings in triplicate, using the Thermo equipment, model Antaris II, equipped with a 4 cm^{-1}-resolution integration sphere, an average of 32 scans and background at each reading, being used for prediction of responses to models developed and validated for the Embrapa Soja laboratory, mentioned above.

Color of the soybeans was evaluated through direct reading of reflectance from the coordinates L*, a* and b*, using a portable, high-precision measurement colorimeter, brand Konika Minolta, model CR-400, with the Hunter system of color, in which: L* has a variable scale from (0 to 100), which indicated the color in terms of light or dark shade, while a* shows greenish with negative values and reddish with positive values and b* assumes positive values for yellowish and negative values bluish shades, both parameters a* and b* varying from (-60 to 60).

Water activity was determined using the Aqua. Lab equipment (BrasEq®) previously calibrated with water and later with saturated solutions of LiCl 0.112, $MgCl_2$ 0.380 and NaCl 0.75. The soybean flour samples were then placed in plastic quantifier containers, and readings were performed in triplicate.

The data obtained in the quantification of the variables temperature and air relative humidity inside the bags over the evaluated period were presented in graphical form and in terms of mean of the top, center and base positions of each bag silo. For the data of protein and oil contents, a completely randomized experiment was used, in a split-plot design, where the sources of variation, the evaluation position (top, center and bottom) were considered considered as a plot; and the storage periods (0, 45, 100 and 125 days of storage) the sub-plots, with nine replicates. The data were tested for normality, homogeneity of variances and finally evaluated using the F test in the analysis of variance at the level of 5% probability; and when significant effects occurred, the Tukey's multiple comparison test was used.

For the data obtained in the product color analyses, linear regression models were adjusted, correlating the dependent variables with the storage time variable where the data were previously tested for normality, homogeneity of variances and eventually, the significance of the coefficients tested by means of F statistic at the 5% level.

RESULTS AND DISCUSSION

Figure 2 shows the mean values collected for the air temperature in the intergranular space of the grain mass within the three evaluated bags. It can be seen a tendency to increase the temperature as storage time evolves, with a homogeneity in the mean values in the 40–100-day period.

In all the bags, the average rise of 5°C was observed, comparing the beginning to the end of the collections, presumably, the thermal variations recorded in the three measurement points, were, in part, inherent to the external environmental changes, with the change of winter season for spring in the region. Temperature rises may have contributed to the increase in the metabolic rate of the product and the consequent loss of dry matter stored mass.

The chemical reactions involved in the respiratory process are controlled by enzymes and the increment in the grain moisture promotes biological activity because the enzymes and the substrate are more easily mobilized for the respiration process. The higher the temperature, the greater the metabolic activity of the grains, thus increasing the deterioration of the raw material; however low oxygen reduces the acidity, activity of the peroxidase enzyme in grains, parameters related to the quality of soybeans (ALENCAR *et al*., 2010).

The increase in the air relative humidity shown in Figure 3 can be explained by some reasons, such as the metabolic activity of the product that in addition to heat releases water, a by-product of the respiratory process (OCHANDIO *et al*., 2017), consequently leaving the environment conducive for the appearance of moldy grains (Table 3). Variations were observed in relative humidity, with a maximum amplitude of 73% and a minimum of 59%, respectively (Figure 2).

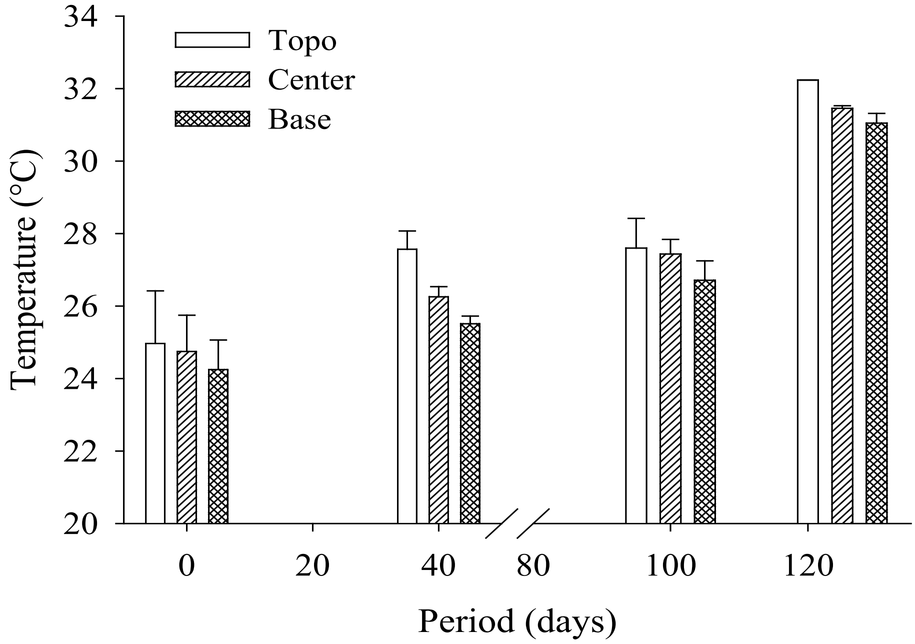

Figure 2. Average values for air temperature in the intergranular space of the grain mass in three bag silos, with measurements carried out over 125 days

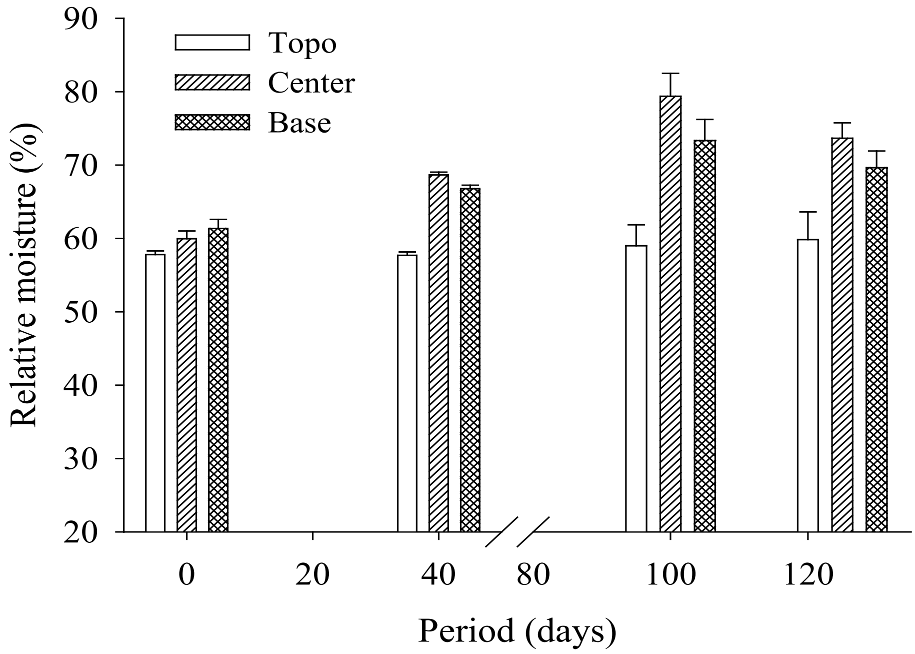

Figure 3. Average values for air relative humidity in the intergranular space of the grain mass in three bag silos, with measurements carried out over 125 days

Table 3 shows the mean values of the classification of the beginning and end of the grain storage process in the bag silos. It is observed an increase in the percentage of fermented grains from 2.63% to 8.17%, and the appearance of moldy grains (3.07%) during the experiment. The increase in the percentage of these classification defects may have been influenced by the raise in the temperature and air relative humidity variables in the bag (Figures 1 and 2).

As a result, we highlight the complexity of the storage dynamics within the structure of the bag silo, with changes in the internal atmospheric conditions, especially in the third data collection at 100 days, and evolution of soybean defects, as observed by the classification data of the product (Table 3). At the beginning of storage, the grains presented a group and type-1 quality standard, that is, they could be destined for fresh consumption. After 125 days in the bag silo, soybeans showed a total of more than the maximum tolerated limits for the quality-2 group.

Figure 4 shows the behavior of the water content parameter of soybeans (%) as a function of storage period. A significant statistical effect ($p < 0.05$) of the storage time was found on the response variable, with the increase in the period of permanence of the product in the bag, the reduction in the water content in the product. This change can be explained and related to the hygroscopic characteristic of the grains that may yield or absorb water from the environment in which they

Table 3. Mean values, expressed as a percentage for plant classification in three bag silos, with measurements taken at the time of loading the bags (zero time) and after 125 days of storage

Classification	Zero time	125 days
	%	%
Water content	11.5	10.75
Foreign material and Impurity	0.37	0.27
Broken/Cracked	7.33	7.6
Elongated grain	0	0
Opaque /Greenish	0	0
Blazed	0	0
Burnt	0	0
Moldy	0	3.07
Fermented	2.63	8.17
Germinated/Sprouted	0	0
Insect-damaged	1.47	0.73
Immature	0	0
Dry	0	0
Broken total	4.1	11.97

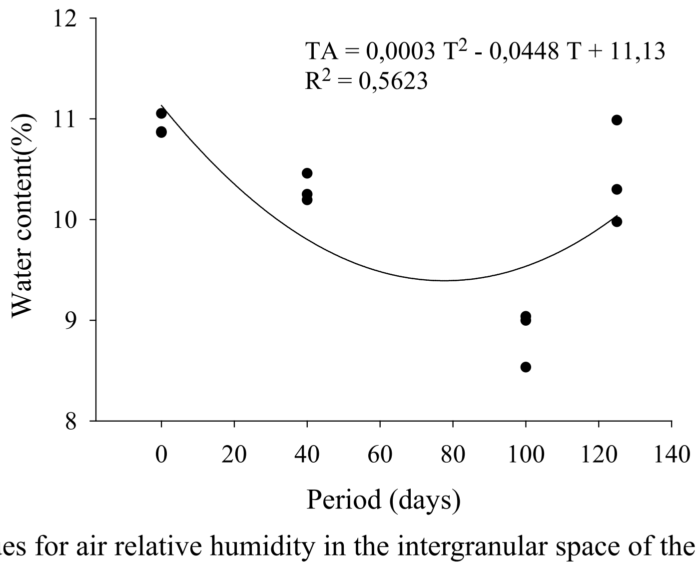

Figure 4. Average values for air relative humidity in the intergranular space of the grain mass in three bag silos, with measurements carried out over 125 days

are stored. The increases in relative humidity previously observed in Figure 3, demonstrate this behavior of changing the water from the grain to the air in the intergranular space, in view of the increase in the relative humidity values.

The average protein content in the soybean grain, in different positions and storage periods in the bag silo is shown in Table 4. It can be observed that there were no significant changes, as it occurred in the analysis of variance p = 0.8170 for the variation between the evaluated positions and the storage period, the F test pointed to p = 0.4156. Therefore, the effects of the two sources of variation, plots (positions on the bag) and sub-plots (storage periods) did not influence the content of this quality parameter of the grain stored for 125 days in a bag silo, presenting a general average value of 36.92%. These results were also presented by Ziegler *et al*. (2016), who observed the maintenance of protein content in soybeans stored in a bag silo with different water contents for 240 days.

The lipid content of soybean was not significantly influenced by the source of variation position (plots), with p = 0.6283; therefore, greater than 0.05, which is the adopted level of significance. However, according to the variation of the sub-plots, storage periods, a significant statistical effect (p = 0.010) was found with differences among the means, shown in Table 5. Over the 125-day period, an increase in the oil content was observed in soybeans stored in bag silo, with mean values at the beginning of storage from 22.37% to 23.02%, at the end of the process. These means are statistically different. Alencar *et al*. (2009) found in stored soybean grain, a reduction in the lipid content of stored grains with a water content of 14.8% at temperatures of 30 and 40°C indicating lipid oxidation processes; that is, a behavior opposite to that found in this work. Schultz *et al*. (2018) also state that lipid degradation increases when soybeans are stored with higher water content and under conditions of higher oxygen concentration. Thus, it is suggested that in the hermetic conditions in which the product remained, this oxidation and deterioration of the oil were not favored. In legumes such as soybean, lipids are stored in small organelles, denominated lipid bodies, located in cotyledons and composed mostly of triglycerides (ESKIN, SHAHIKI, 2015). Also, according to the same authors, the synthesis of these compounds is controlled by the regulation

Table 4. Protein content (%) in soybean grains stored in bag silo at different positions and storage period

Position	Period				
	0	40	100	125	Mean
Base	37.22 ± 1.79	36.77 ± 1.02	36.68 ± 0.93	36.66 ± 1.79	36.83^{A}
Center	37.17 ± 0.68	36.96 ± 0.96	37.03 ± 0.68	36.72 ± 0.68	36.97^{A}
Top	36.87 ± 1.07	37.28 ± 1.03	37.08 ± 0.63	36.58 ± 1.07	36.95^{A}
Mean	37.09 ± 1.18^{a}	37.01 ± 1.01^{a}	36.93 ± 0.91^{a}	36.65 ± 1.18^{a}	

* mean value ± standard deviation; lowercase letters in the row and uppercase letters in the column correspond to statistically equal means by the Tukey's multiple comparison test 5% significance level

Table 5. Lipid contents (%) of soybean grain stored in bag silo in different positions and storage periods

Position	Period				
	0	40	100	125	Mean
Base	22.30 ± 1.01	22.54 ± 0.49	22.72 ± 0.93	23.23 ± 0.90	22.69^{A}
Center	22.44 ± 0.41	22.53 ± 0.82	22.84 ± 0.68	22.49 ± 0.64	22.57^{A}
Top	22.39 ± 0.47	22.62 ± 0.65	22.57 ± 0.63	23.34 ± 0.64	22.73^{A}
Mean	22.37 ± 0.63^{b}	22.56 ± 0.66^{b}	22.71 ± 0.75^{ab}	23.02 ± 0.73^{a}	

* mean value ± standard deviation; lowercase letters in the row and uppercase letters in the column correspond to statistically equal means by the Tukey's multiple comparison test at the 5% significance level

of the levels of fatty acids in biosynthetic proteins; therefore, it is suggested that under the conditions of this study, this may have resulted in an increase in the lipid content.

A significant decrease ($p < 0.05$) was observed in the brightness color parameter (*) as a function of the storage period in a bag silo in the period of 125 days. As the * parameter indicates absolute white (+100) or absolute black (-0) at its ends, it is observed that the grains moved away from the lighter tones, L* = 63.36 to the darker ones, L* = 55.64 at the end of the storage period (Figure 5). This darkening of the grains may be related to the appearance of moldy and fermented grains over the stored period due to the increase in temperature and relative humidity. Such results corroborate with Yousif (2014), when it was observed that the increase in temperature and relative humidity in storage promotes greater darkening of the grains.

It is found that the parameter a* was not influenced by the storage period ($p > 0.05$), so that the mean values were positive, indicating that the grains presented a greater presence of green color (Figure 6), which was demonstrated in the

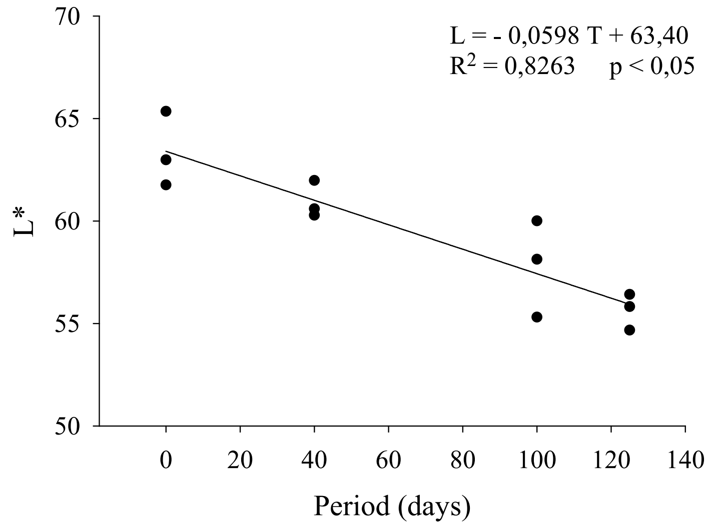

Figure 5. Values of the color parameter L* of soybeans stored in bag silo as a function of the storage period over 125 days

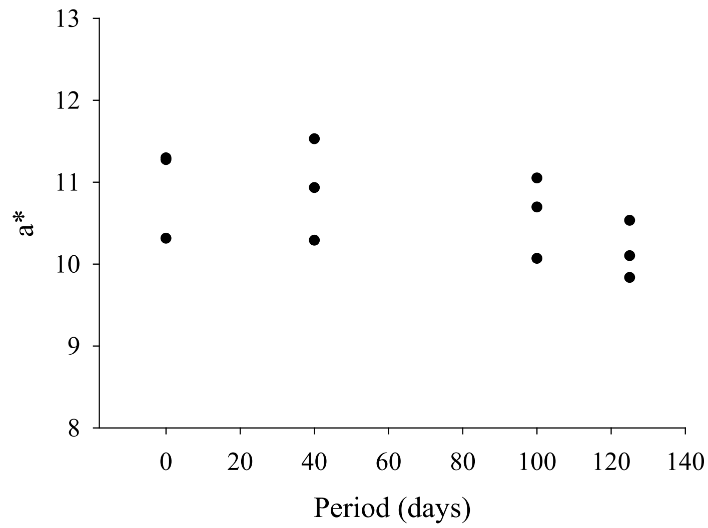

Figure 6. Values of the color parameters a* of soybean grain stored in a bag silo as a function of the storage period over 125 days

appearance of moldy grains shown in Table 3, since parameter a* varies from red to green on a scale from (+60) to (-60). These effects that Ziegler (2014) observed in his experiment, stating that the relative humidity influences more than the temperature for maintaining the color in storage.

Figure 7 shows the values of the color parameter b* over the storage period of 125 days in bag silos. The parameter b* changes from yellowish to bluish shade. There was a significant influence ($p < 0.05$) of the storage time.

Such results corroborate with Alencar *et al.* (2009), who verified changes in the color of soybean grain during storage, with an increase in the water content and temperature of the beans, also associating with the development of fungi.

The mean values of water activity (aw) ranged from 0.6084 to 0.6023 for the 0-125-day storage range in a bag silo. A small variation was observed over time, which was not affected by storage conditions (Table 6).

It was found that the aw values were below the optimal threshold for the development of fungi and bacteria, which is 0.70 - 0.75 (aw) (FLEURAT-LESSARD, 2017). Also, according to Ochandio *et al*. (2017), the increase in the water content of the product will increase the incidence and speed of some enzymatic reactions that will consume oxygen. Therefore, values below 0.7 (aw) associated with water content (Figure 4), indicate that the grains reached metabolic stability during storage.

Aw values greater than 0.85 in the grains promote the growth of fungi that cause mycotoxins, insects, as well as the metabolic activities of the grains, such as respiration and subsequent heat generation. When aw is lower than that value, the grain reaches biological safety, reduces degradation through lower respiration rate, enzymatic activity and proliferation of microorganisms (MOHAPATRA *et al*., 2017).

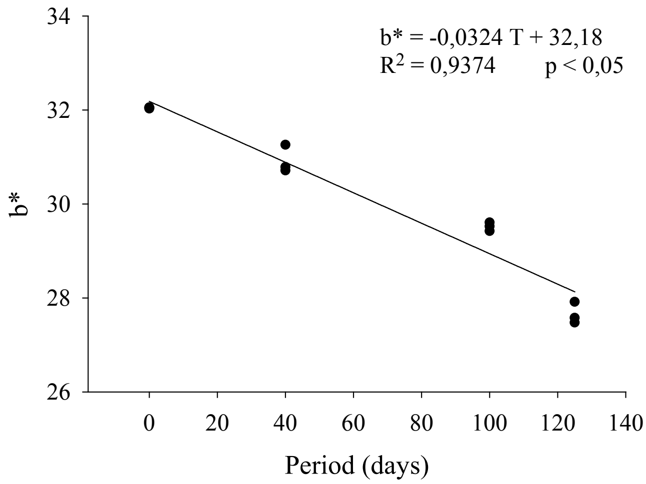

Figure 7. Values of the color parameters b* of soybean grain stored in a bag silo as a function of the storage period over 125 days

Table 6. Mean values of water activity (aw) in soybean grain as a function of storage period

Period (days)	Water activity (aw)
0	0.6084 ± 0.0483
40	0.6023 ± 0.0234
100	0.5419 ± 0.0319
125	0.6023 ± 0.0327

CONCLUSIONS

Based on the results found under the conditions in which this experiment was executed, it can be inferred that:

- Soybean grain can be stored with a water content close to 11% at temperatures between 24 – 32°C for 125 days in the bag silo in a tropical climate without significant changes in protein levels. However, the color parameters of the grain were significantly changed, which resulted in the darkening of the product. The lipid content in the soybean grain stored in the bag was influenced by the storage time, implying an increase in concentration in relation to the initial time.
- The rise in temperature and relative humidity in the storage caused changes in the metabolic processes of the grains, which increased the rates of moldy and fermented defects, reducing commercial quality, as a consequence.
- The mean values of water activity were ideal for the biological safety of the grains

AUTHORSHIP CONTRIBUTION STATEMENT

PINTO, V.D.; DIAS, L.M.; OLIVEIRA, M.A.: Methodology, Investigation, Formal analysis. HOSCHER, R.H: Supervision, Writing. GOMES, F.R: Data curation, Formal analysis. SCHOENINGER, V.: Writing, Review, Supervision.

ACKNOWLEDGMENTS

To Copasul (*Cooperativa Agrícola Sul Matogrossense*) for the structure for the execution of the experiment and to Bípedes Sistemas Soluções e Consultorias, for the availability of the technological structure (sensors and applicative). To the Federal University of Grande Dourados and Embrapa Soja, both for the availability of laboratories.

We have no conflict of interest to declare.

REFERENCES

ALENCAR, E. R.; FARONI, L. R. D.; PETERNELLI, L. A.; SILVA, M. T. C.; COSTA, A. R. Influence of soybean storage conditions on crude oil quality. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 14, n. 3, p. 303-308, 2010.

ALENCAR, E. R.; FONI, L. R. D.; FILHO, A. F. L; PETERNELLI, L. A.; COSTA, A. R. Qualidade dos grãos de soja armazenados em diferentes condições**. Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 13, p. 606-613, 2009.

BARRETO; A. A.; ABALONE, R.; GASTÓN, A.; OCHANDIO, D.; BARTOSIK, R. Validation of a heat, moisture and gas concentration transfer model for soybean (*Glycine max*) grains stored in plastic bags (silo bags). **Biosystems Engineering**, v. 158, n.1. p.23-37, 2017.

BRASIL, Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. **Regras para análise de sementes**. Brasília, DF: Mapa/ACS, 2009.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento (MAPA). **Instrução Normativa nº 11 de 15 de maio de 2007.** Diário Oficial da União, Brasília, 14 dez. 2006. Seção 1, 9 p.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento**. Instrução Normativa nº 29 de 08 de junho de 2011**. Diário Oficial da União, Brasília, 09 jun. 2011. Seção 1, p. 9-15.

CARPANETO, B.; BARTOSIK, R.; CARDOSO, L.; MANETTI, P. Pest control treatments with phosphine and controlled atmospheres in silo bags with different airtightness conditions. **Journal of Stored Products Research**, v. 69, p. 143-151, 2016.

Companhia Nacional De Abastecimento - CONAB. **Acompanhamento da safra brasileira de grãos. Safra 2019/2020 – sexto levantamento**, Brasília, DF, v. 7, n. 6, p. 1- 29, 2020.

ESKIN, N.A.M.; SHAHIDI, F. Bioquímica de alimentos. 3a Edição. Rio de Janeiro: Elsevier, 2015.

FARONI, L. R. A.; ALENCAR, E. R.; PAES, J. L.; COSTA, A. R.; ROMA, R. C. C. Armazenamento de soja em silos tipo bolsa. **Engenharia Agrícola**, v. 29, n. 1, p. 91-100, 2009.

FLEURAT-LESSARD, F. Integrated management of the risks of stored grain spoilage by seedborne fungi and contamination by storage mould mycotoxins – An update. **Journal of Stored Products Research**, v. 71, p. 22-40, 2017.

FREITAS, R. S.; FARONI, L. R. A.; SOUSA, A. H. Hermetic storage for control of common bean weevil, Acanthoscelides obtectus (Say). **Journal of Stored Products Research**, v. 66, p. 1-5, 2016.

KONG, F.; CHANG, S. K. C. Changes in protein characteristics during soybean storage under adverse conditions as related to tofu making. **Journal of Agriculture and Food Chemistry**, v. 61, p. 387-393, 2013.

MOHAPATRA,D.;KUMAR,S.;KOTWALIWALE, N.; SINGH, K. K. Critical factors responsible for fungi growth in stored food grains and non-Chemical approaches for their control. **Industrial Crops and Products**, v. 108, p. 162-182, 2017.

OCHANDIO, D.; BARTOSIK, R.; GASTÓN, A.; ABALONE, R.; BARRETO, A. A.; YOMMI, A. Modelling respiration rate of soybean seeds (Glycine max (L.)) in hermetic storage. **Journal of Stored Products Research,** v. 74, n. 1, p. 36-45, 2017.

SCHULTZ, R. A.; CORADI, P. C.; BRENTAN, L. O., CAMILO, L. J. **Efeitos das condições de armazenamento no rendimento do óleo de soja**. 2018. Disponível em: <https://maissoja.com.br/efeitos-das-condicoes-de-armazenamento-no-rendimento-do-oleo-de-soja/ > Acesso em 29 mar. 2020.

TAHER, H. I.; URCOLA, H. A.; CENDOYA, M.G.; BARTOSIK, R. E. Predicting soybean losses using carbon dioxide monitoring during storage in silo bags. **Journal of Stored Products Research**, v.82, n.1, p. 1-8, 2019.

YOUSIF, A. D. Soybean grain storage adversely affects grain testa color, texture and cooking quality. **Journal Food Quality**, v. 37, p. 18-28, 2014.

ZIEGLER, V. **Efeitos da umidade e da temperatura de armazenamento sobre parâmetros de avaliação da qualidade dos grãos, do óleo e de compostos bioativos de soja**. 2014. 110 f. Dissertação de Mestrado (Ciência e Tecnologia de alimentos) - Faculdade de Agronomia, Universidade Federal de Pelotas, Pelotas, 2014.

ZIEGLER, V.; FERREIRA, C.D.; VANIER, N.L.; SANTOS, M.A.Z.; OLIVEIRA, M.; ELIAS, M.C. Physicochemical and technological properties of soybean as a function of storage conditions. **Brazilian Journal of Food Research**, Campo Mourão, v. 7, n. 3, p. 117-132, 2016.