Quality of white Gurgutuba creole beans stored in silo bags and PET bottles

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Abstract

Hermetic storage in silo bag has provided a viable alternative for farms. This study evaluates the use of silo bags as an alternative for storing creole beans. The experiment was conducted in the UFAC seed laboratory. The beans were stored in silo bags for 30, 60, 90 and 120 days or in PET bottles, which is the common practice. In the control treatment, PET bottles sealed with organza fabric were used. The experimental model was factorial CRD with subdivided plots and four replications, with the plots being storage conditions; and sub-plots, storage periods. The degree of infestation, moisture content, apparent specific mass, germination percentage and electrical conductivity were evaluated at 30 - day intervals. There was significant variation ($p < 0.05$) between storage types *Zabrotes subfasciatus* (Boheman) and *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae, Bruchinae), then infestations occurred. Infestation using these bruchids was < 7% in the beans stored in the silo bag and PET bottle. For the control treatment, the degree of infestation was slightly higher ($p < 0.05$) with rates of > 90% after 120 days. The moisture content, specific mass, germination, and electrical conductivity of the beans stored in the silo bag and PET bottle preserved the characteristics analyzed over the 120-day period with the exception of control treatment. Storage in silo bags is an effective alternative for controlling infestation and maintaining quality, in terms of moisture content, specific mass, germination, and electrical conductivity, for up to 120 days.

Keywords: *Phaseolus vulgaris* L. Modified atmosphere. Hermetic. Infestation.

Introduction

Creole bean genotypes are defined as those that have been generated via natural crossings and that have not undergone any genetic improvement process (ELIAS et al., 2007).

The white Gurgutuba bean variety belongs to the species *Phaseolus vulgaris* L., cultivated in dry land areas. It has an indeterminate climber growth habit, with prostrate habit and a tendency to wrap around the support (MATTAR et al., 2016). Usually, these creole varieties are stored on small and medium-sized farms.

With increase in grain and bean productivity in Brazil, the storage of these products presents a systematic deficit in their static storage capacity, thus contributing to significant losses in profitability for farmers (WACHTER; PEREIRA, 2015). The use of new technologies and loss prevention techniques help maintain food stocks (DE LIMA JUNIOR et al., 2012).

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In Brazil, the common bean (*Phaseolus vulgaris* L.) is one of the main primary foods consumed, national production is one of the largest on the planet. The demand from the Brazilian market is considerable, requiring an annual production of 3.0 million tons. However, it is estimated that Brazilian production of the common bean is currently only at 25% of its potential (WANDER et al., 2014).

When it comes to losses in grain/bean production, staple foods for the world's population, factors related to storage, in addition to factors in the field, must be considered.

One of the basic aims of storage is maintaining the characteristics of the grain/beans for a specific time period, thus preserving the quality of the product. Another factor that leads to storage of grain/beans is their market price (LIMA JUNIOR et al., 2012). A considerable amount of Brazil's grain/ bean production is stored in metal or brick (bulk) silos before being sold; however, extended periods in storage can lead to loss of quality of the product (SANTOS; CHAVAGLIA, 2017). The indiscriminate application of pesticides during storage can result in environmental damage, with serious long-term consequences that are often irreversible (BOHNER et al., 2013).

The demand for ecologically generated products is high, and increases every year. Yet, organic production requires the producer to have considerable knowledge of cultivation techniques, as well as the use of varieties with high productivity, which, in turn, requires adequate storage (SOARES JUNIOR et al., 2015). In addition to production, it is essential to store the product correctly to minimize losses of grain/beans, as well as financial and logistical losses (BARONI et al., 2017). The use of the silo bag, a technique in which the product is hermetically stored in sealed plastic bags, provides an alternative to traditional methods for storing grain/beans on farms (COSTA et al., 2010).

It is a mobile system with the bags horizontally stored. The bags are composed of low-density polyethylene, co-extruded in three layers, with a thickness of 0,00025 m and a capacity between 60 and 180 tons. The bags are 1,50, 1,80 or 2,70 m, and 60 m in length (MARCHER BRASIL, 2020). The mobility, low investment cost, space optimization, and easy handling of this system make it a good storage option for small and medium-sized producers.

Considering the above, this study aims to evaluate the quality of white Gurgutuba creole bean seeds stored in silo bags compared to other types of storage.

Materials and methods

The experiment was conducted at the Integrated Pest Management Laboratory of the Postgraduate Course in Plant Production of the Federal University of Acre – Rio Branco campus in Rio Branco/AC, Brazil. Seeds of the Gurgutuba white creole bean variety were directly acquired from the producer in Cruzeiro do Sul – AC, coordinates E-792598.00 N-9141665.21, Zone 18M, from the 2017 harvest. Tests were then conducted to determine the degree of infestation, moisture content, specific mass, germination, and electrical conductivity, for initial characterization of the beans (Table 1).

Table 1 – Initial characterization of the beans (*Phaseolus vulgaris* L.).

Bean characteristics	Variety
	Gurgutuba white
Insect-pest infestation (%)	3.67
Moisture content (% wet basis)	11.12

(continue...)

Table 1 – Continuation

Bean characteristics	Variety
	Gurgutuba white
Apparent specific mass (kg m^{-3})	662.70
Percentage of germination (%)	66.25
Electrical conductivity (μS cm^{-1} g^{-1})	70.38

Source: Elaboration of the authors (2019)

After the initial characterization, the beans were packaged in polyethylene silo bags and polyethylene terephthalate (PET) bottles. The bags had a capacity of 0,5 kg (0,3 × 0,2 m rectangular packs) with 0,00025 m thick plastic, comprising three layers; black on the inside and white on the outside, with UV stabilizers, and sealed using a multipurpose sealing machine (0,4 m hot bar). The PET bottles were properly sealed using a screw cap. The plastic bottles were reused, and were transparent, with a capacity of 0.6 L and a thickness of 0,00027 m. In terms of the control treatment, they were sealed with organza fabric, to allow the exchange of gases between the inner ecosystem of the bottles and the external environment. The experiment was then conducted in a controlled environment for 30, 60, 90, and 120 days, at a temperature of 25 ± 1.5°C, and relative humidity of 76% ± 12.5%. The evaluations were then conducted every 30 days.

To evaluate the degree of infestation, two samples of 100 creole bean seeds, selected randomly, were immersed in water for 24 h. After this period, the beans were removed from water and dried on paper towels, cut, and individually examined. The beans were considered to be infested as per the protocol described in the Rules of Seed Analysis – RAS (BRAZIL, 2009).

To determine the moisture content of the beans, 30.0 g in triplicate were used for each one of the four repetitions. These samples were placed in a greenhouse, with forced air convection and heating was regulated at 105 ± 3 °C for 24 h. After this period, the samples were weighed using an analytical balance, with a precision of 0.01 g. The routine described in Regras de Análises de Sementes [Rules of Seed Analysis] – RAS (BRAZIL, 2009) was adopted.

The apparent specific mass was determined using a hectoliter scale with capacity of 250.0 ml. Triplicate readings were performed for each sample, and the simple mean of the three was selected. As the hectoliter weight of a sample varies as per its moisture content, the determinations were simultaneously performed (BRAZIL, 2009).

The percentage of germination was measured using eight repetitions of 50 beans each, placed on two sheets of standard paper substrate, previously moistened with distilled water at a proportion of 2.5 times the weight of the paper, and then covered by another sheet of the same moistened paper, and wrapped into rolls. The rolls were horizontally placed into the germinator, and maintained at a temperature of 25 ± 1 °C. The count was performed at the end of the ninth day, after sowing with the protrusion of the integument considered as indicative of germination, a protocol described in the Regras de Análises de Sementes – RAS (BRAZIL, 2009).

For the variable electrical conductivity of the solution, three repetitions of 50 beans were randomly selected from each treatment. The beans were weighed on a scale with a precision of 0.01 g, and placed in plastic cups with a capacity of 200 ml, to which 75 ml of distilled water was added. The cups were then placed in a BOD climate chamber at 25 °C for 24 h. After this period, they were removed from the chamber; therefore, the electrical conductivity of the solution containing the beans could be measured using a bench conductivity meter. The electrical conductivity value (µS cm^{-1}) provided by the properly calibrated apparatus was divided by the total mass of the beans to obtain the value, expressed as µS cm^{-1} g^{-1} of total mass (VIEIRA; CARVALHO, 1994)

Was used in factorial a scheme of subdivided plots with four replications. The plots represented the storage conditions (silo bag, PET bottle, and control) and the subplots, i.e., the five storage periods (0, 30, 60, 90, and 120 days). The data were submitted for verifying the normality of the residuals (Shapiro; Wilk, 1965) and homogeneity of the variances (COCHRAN, 1957). The normality of residuals and the homogeneity of variances having been observed, the analysis of variance (F test) was performed at a 5% level of probability.

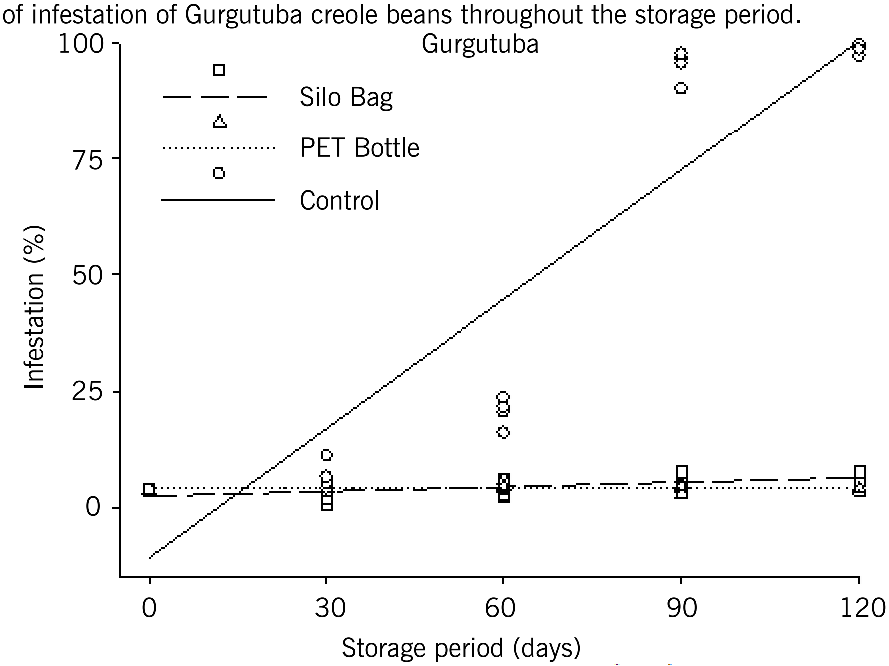
The storage conditions were then compared using Tukey's test at a 5% probability. Data on moisture content, apparent specific mass, electrical conductivity, germination percentage, and degree of infestation were submitted to analysis using *SISVAR* version 5.6 (FERREIRA, 2014). For significant interactions, regression analyses were performed as a function of time using *SigmaPlot* ® (SPSS, 2006).

Results and discussion

It was possible to identify the presence of *Zabrotes subfasciatus* (Boheman) and *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae, Bruchinae) in the beans. These species present primary feeding habits and are of recognized economic significance (Faroni; Sousa, 2006). The degree of insect pest infestation in the creole bean seeds significantly varied during storage ($F_{4,36}$ = 1667.41; $p \leq 0.01$) and between the systems ($F_{2,36}$ = 1777.50; $p \leq 0.01$), and there was interaction ($F_{8,36}$ = 1512.30; $p \leq 0.01$) at the end of the 120-day period.

The results of infestation by *Z. subfasciatus* and *A. obtectus* in the beans of the Creole bean during the storage period are shown in Figure 1 and Table 2. Were adjusted to regression models only for the characteristics that showed significant variation with the storage period. Characteristics that did not showed significant variation were represented using their mean values.

Figure 1 – Degree of infestation of Gurgutuba creole beans throughout the storage period.



Source: Elaboration of the authors (2019).

Table 2 – Mathematical models used to represent the values throughout storage in each storage system.

Variable	Storage	Fitted Equations	g.l.error	F	*P*	R^2
Degree of Infestation	Silo bag	$\hat{y}$ = 2.4520+0.0330x	18	20.56	0.0003	0.53
	PET bottle	$\hat{y}$ =4.13	-	-	-	-
	Control	$\hat{y}$ = 10.7730+0.9264x	18	96.71	< 0.0001	0.83
Moisture Content	Silo bag	$\hat{y}$ = 11.67	-	-	-	-
	PET bottle	$\hat{y}$ = 11.43	-	-	-	-
	Control	$\hat{y}$ = 10.4815+0.0589x	18	92.51	< 0.0001	0.83
Apparent Specific Mass	Silo bag	$\hat{y}$ = 666.14	-	-	-	-
	PET bottle	$\hat{y}$ = 656.8640+0.1531x	18	23.63	0.0001	0.56
	Control	$\hat{y}$ = 676.3025 - 0.6127x	18	35.93	< 0.0001	0.66
Percentage of Germination	Silo bag	$\hat{y}$ = 60.3750 - 0.2600x	18	72.13	< 0.0001	0.80
	PET bottle	$\hat{y}$ = 62.1750 - 0.2821x	18	207.64	< 0.0001	0.92
	Control	$\hat{y}$ = 65.6375 - 0.5933x	18	480.32	< 0.0001	0.96
Electrical Conductivity	Silo bag	$\hat{y}$ = 68.1440+0.1571x	18	11.29	0.0035	0.38
	PET bottle	$\hat{y}$ = 68.3690+0.1317x	18	89.08	< 0.0001	0.83
	Control	$\hat{y}$ = 53.4455+0.8253x	18	51.09	< 0.0001	0.73

Source: Elaboration of the authors (2019).

The infestation degree in the beans stored in silo bags was significant ($p \leq 0.05$) (Table 2); however, it was constant during all storage periods, and did not sufficiently increase to cause a marked depreciation of the product, except for the control treatment (Figure 1). In the same figure, the linear model satisfactorily represents the experimental values, thus being significant at 1% probability according to the Tukey test, with acceptable values in the literature for the coefficient of determination (R^2). Storage type x storage period interaction occurred with the beans stored in silo bags and PET bottles presenting the lowest infestation rate.

The differences observed are related to genotypic characteristics (COELHO et al., 2010) or to the occurrence of cross-infestation (BRAGANTINI, 2005). In this study, the results obtained corroborate the understanding of Rodriguez et al. (2019), who described the hermetic environment in silo bags as a cause of O_2 reduction and CO_2 increase, thus discouraging insect reproduction. Under airtight conditions, the oxygen level sharply decreased, primarily because of respiration of the beans (NAVARRO, 2012a; 2012b; NJOROGE et al., 2014). As the level of carbon dioxide increased, the insects stop feeding and eventually died from asphyxiation or desiccation (NJOROGE et al., 2014). The occurrence of *A. obtectus* and *Z. subfasciatus* weevils may be associated with cross-infestation; moreover, when the infestation occurred, the product loses quality. Furthermore, there may be a decrease in the percentage of germination and vigor among other losses (SILVA et al., 2013). According to Freitas (2009), the storage of grains in silo bags presents clear results and emerges as a viable alternative in the control of pest insects. However, under non-hermetic storage conditions, infestation rates exponentially grow during storage. For certifying beans, up to 3% infestation is tolerated by the Ministry of Agriculture, Livestock and Food Supply (MAPA, 2013). The results obtained for the tested variety extrapolates to the parameters set using MAPA.

Figure 2 and Table 2 show the results for moisture content for the beans of the white Gurgutuba variety. The moisture content of the creole beans significantly varied throughout the storage ($F_{4,36}$ = 108.93; p ≤ 0.01) and between systems ($F_{2,36}$ = 584.11; p ≤ 0.01); and there was also interaction ($F_{8,36}$ = 121.06; p ≤ 0.01) as per the variance analysis summary.

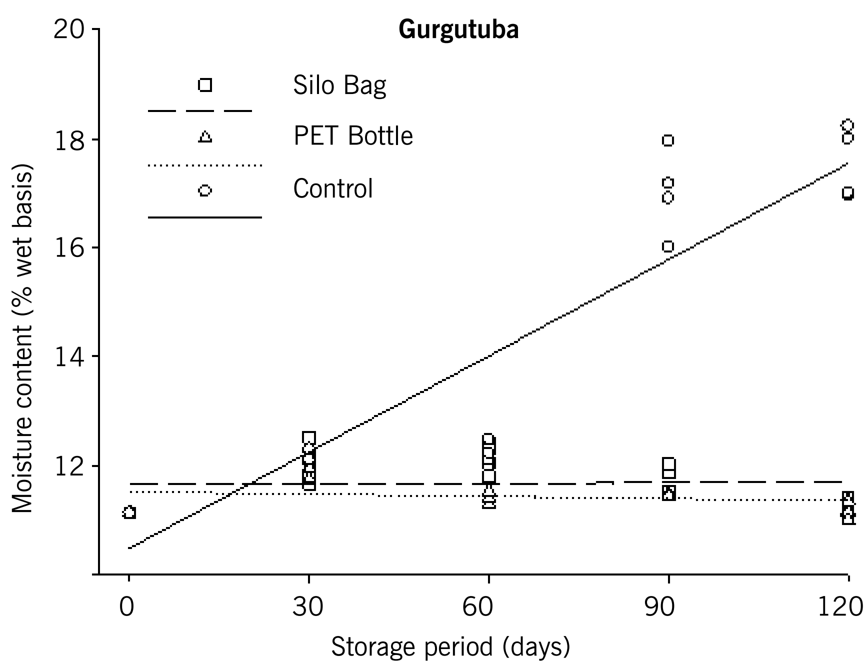
The data were adjusted for regression models only for the characteristics that showed significant variation with the storage period.

The moisture content of the beans did not significantly vary (p ≥ 0.05) over the 120 days of storage in the silo bag and PET bottle treatments, unlike the control treatment, which presented a greater increase (p ≤ 0.05) than the other treatments (Figure 2).

Throughout the storage period, the moisture content of the beans stored in silo bags and PET bottles remained constant. The linear model used adequately represents the experimental values and remained significant at 1% probability according to the Tukey test and presenting a significant value for the coefficient of determination (R^2). There was interaction between the type and period of storage. Moreover, there was no significant difference between the silo bag and PET bottle treatments at the end of the 120-day period; however, they statistically differed (p ≤ 0.05) from the control treatment.

Schneider et al. (2014), working with the common bean, observed that storing beans in impermeable packaging for 120 days in a controlled environment preserved their physiological and sanitary quality. The results obtained corroborate those reported by da Costa et al. (2010), who observed that there was no increase in the moisture content of hermetically stored corn grains. The effect of hermetic storage on grains is corroborated by the study with triple-layer plastic packaging (MUTUNGI et al., 2015), with similar results to this study being obtained.

Figure 2 – Moisture content of Gurgutuba creole beans throughout the storage period.



Source: Elaboration of the authors (2019).

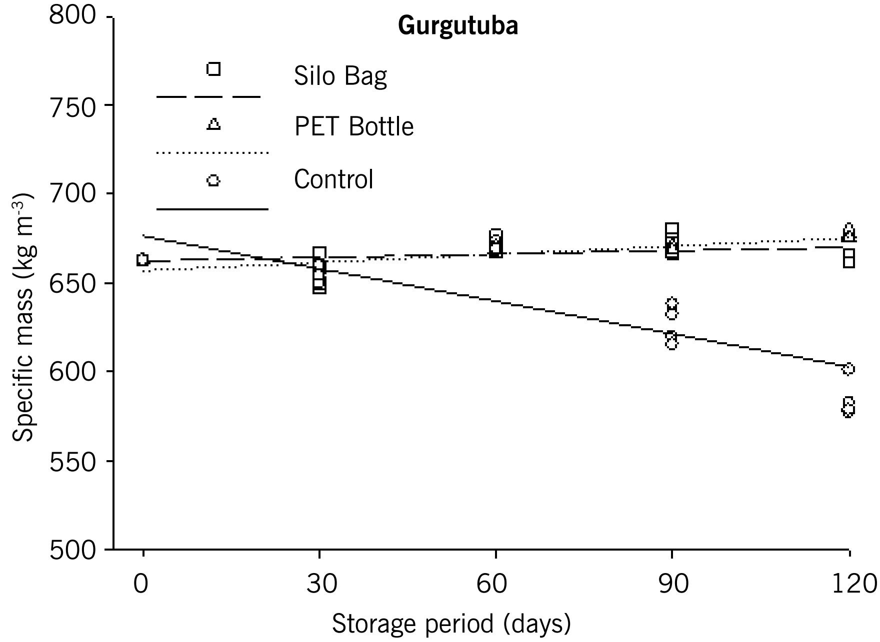
The results obtained for the apparent specific mass of the creole beans throughout the storage period significantly varied ($F_{4,36}$ = 45.45; p ≤ 0.01) and between the systems ($F_{2,36} =332.00$; p ≤ 0.01), and there was interaction too ($F_{8,36}$ = 70.40; p ≤ 0.01). Figure 3 and Table 2 show the results for the apparent specific mass during storage, which show that the apparent specific mass of the creole beans stored in the control was lower than the apparent specific mass of those stored under hermetic conditions. The losses of apparent specific mass recorded during storage of Gurgutuba bean seeds in the control treatment are associated with increased moisture content, favored by the presence of insects, which was observed starting at 30 and 60 days of storage, respectively (Figure 2). The linear regression model satisfies the experimental value with the 1% probability being significant as per the Tukey test and showing significant values for the coefficient of determination (R^2) (Table 2).

Interaction occurred for the specific mass variable in the Gurgutuba creole variety, and the value of the specific mass of the beans stored in the silo bag did not decrease during storage. The silo bag and PET bottle treatments showed the least increases over the storage period (Figure 3).

The bean seeds stored in the silo bag and PET bottles presented the best results (p ≤ 0.05) in relation to the control treatment. As stated by Freitas et al. (2011), recorded losses in the apparent density of the stored grains may be associated with increased moisture content, and the presence of fungi and insect-pests, starting at 60 days. However, for Di Lanaro (2011), reduced grain density values can be explained by the lower density of water compared to other components. With increase in grain dimensions, the porosity increases, thus reducing the apparent density. According to Jesus et al. (2013), moisture content is inversely proportional to the apparent specific mass. For Freitas (2009), the similar behavior of grains in storage systems may be primarily associated with low moisture content and the absence of fungi because a reduction of the water metabolized in the respiratory process of grains occurs, thus conserving the moisture content of the grain mass.

Both the silo bag and PET bottle storage systems presented greater specific mass (p ≥ 0.05), suggesting their efficacy in maintaining this variable over the 120-day storage period. Costa et al. (2010), working with corn stored in silo bags, concluded that there was no significant decrease in the apparent specific mass of the product during storage under the conditions tested. Walnut et al. (2014) examined the validation of a mathematical model for corn storage and concluded that the bag silo system is a viable technique for grain storage.

Figure 3 – Specific mass of Gurgutuba creole beans over the storage period.



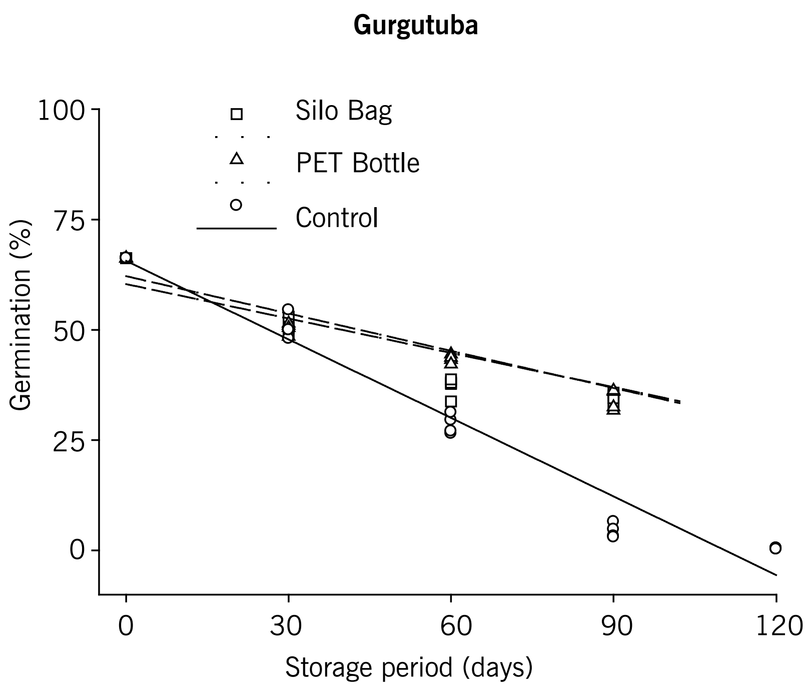
Source: Elaboration of the authors (2019).

The results for the variable germination in the creole beans varied significantly throughout the storage period ($F_{4,36}$ = 1511.53; $p \leq 0.01$) and between the systems ($F_{2,36}$ = 812.83), and there was interaction between these factors ($F_{8,36}$ = 130.62; $p \geq 0.01$). Figure 4 and Table 2 show the results obtained for the germination percentage of creole beans during storage. Regression models were adjusted only for the characteristics that showed significant variation during the storage period. The characteristics that did not showed significant variation were represented by the means of their values.

During the storage period, it was observed that the germination of the beans of the creole varieties stored in the control treatment was lower ($p \leq 0.05$) compared to the germination percentage of the grains stored in the silo bag and PET bottle (Figure 4), which was the most pronounced result in the control. The linear model satisfactorily represents the experimental values, with significance at 1% probability according to the Tukey test, thus presenting acceptable values for the coefficient of determination (R^2). There was interaction between type of storage and storage period, and depending on the storage type, the percentage of germination of the beans was affected throughout the storage period. The germination percentage of the Gurgutuba variety beans in the silo bag and PET bottle storage linearly reduced over the storage period; however, this reduction was greater in the control treatment. At the end of 120 days of storage, a significant difference ($p \leq 0.05$) between storage types was observed, with the silo bag and PET bottle treatments proving to be better at the end of 120 days.

According to Silva et al. (2018), the negative increment is greater in the control treatment with a reduction of up to 100% in germination. The percentage of germination proportionally decreased as the moisture content of the grains increased (Figure 4), thus establishing a possible correlation. However, the decrease in germination percentage may be associated with losses recorded in the degree of infestation because the adjustments made in the regression model for these variables presented similar trends in the quality of the beans (Figure 2). These results are corroborated by Silva et al. (2018), when they established correlations suggesting that moisture content and electrical conductivity increased with increase in the degree of infestation and that the specific mass and germination decreased with increase in the degree of infestation. A percentage of germination of > 70% is a minimum standard required by the Ministry of Agriculture, Livestock, and Food Supply for marketing (MAPA, 2013). In the initial characterization, this variable was already below the required standards; however, the negative increase was lower in the silo bags and PET bottles. The differences between genotypes suggest that there is genetic variability and that this aspect is influenced by the environment (MICHELS et al. 2014).

Figure 4 – Germination of Gurgutuba creole beans throughout the storage period.



Source: Elaboration of the authors (2019).

The results for the electrical conductivity of the creole beans significantly varied throughout the storage period ($F_{4,36} = 39.42$; $p \leq 0.01$) and between the systems ($F_{2,36} = 112.64$; $p \leq 0.01$), and there was interaction too ($F_{8,36} = 16.34$; $p \leq 0.01$).

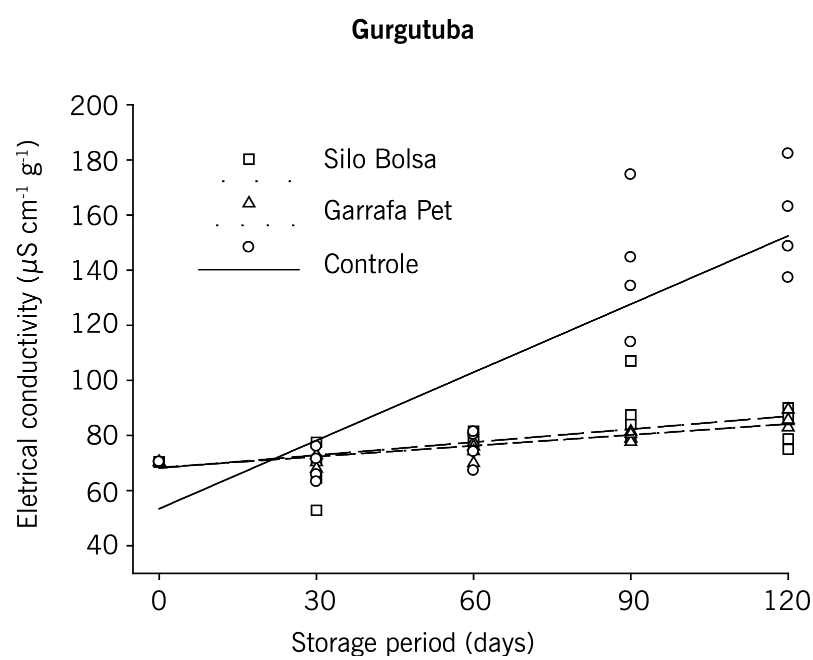
Figure 5 and Table 2 show the results of electrical conductivity of the creole beans throughout the storage period. Regression models were adjusted only for the characteristics that showed significant variation. The characteristics that did not show significant variation were represented by the means of their values. The linear model adequately represents experimental data, being significant at 1% probability as measured by the Tukey test, and presenting acceptable values for the coefficient of determination (R^2). Interaction between storage type and storage period occurred and it was observed that, depending on the type of storage, electrical conductivity values are affected throughout the storage period (Figure 5). The electrical conductivity of the solution containing the beans significantly varied ($p \leq 0.05$) over the storage period in the silo bag and PET bottle systems (Table 2); however, this variation was insignificant in relation to the control treatment ($p \leq 0.01$). The increase in electrical conductivity in the solution containing the beans was more significant in the control treatment after

60 days (Figures 5), which indicates considerable electrolytic leaching of cell solutes in these seeds. The results indicate the effectiveness of the silo bag and PET bottle storage systems, which presented low leaching of solutes from the stored seeds.

It Is noteworthy that there was no significant difference ($p \geq 0.05$) in the mean electrical conductivity at the end of 120 days between storage types, except for the control treatment, thus highlighting the silo bag and PET bottle treatments as the best at the end of 120 days.

For Zambiasi (2015), the storage time directly influences the values of electrical conductivity, starting at 60 days. However, Pereira et al. (2007) correlated the increase in the electrical conductivity values of the bean solution with the degree of infestation by insect pests, thus confirming the results obtained in this study (Figure 1). For Filho (2015), high concentrations indicate high leaching in solutes and are related to poor quality beans. Cassol (2017) states that leaching of electrolytes indicates lower stability of the plasma membrane; therefore, the higher the value of electrical conductivity the more it interferes with grain quality because of the release of mineral ions. In this study, the increase in electrical conductivity obtained may be associated with the increase in moisture content as well as the high degree of infestation by pests (Figures 1 and 2). Silva et al. (2018) established correlation analyses, suggesting that moisture content and electrical conductivity increased with increase in the degree of infestation and that the specific mass and germination decreased with increase in the degree of infestation.

Figure 5 – Electrical conductivity of Gurgutuba creole beans throughout the storage period.



Source: Elaboration of the authors (2019).

Conclusion

Hermetic storage in silo bags and PET bottles are effective alternatives to control infestation by insect pests (*A. obtectus* and *Z. subfasciatus*), and do not compromise the physiological qualities of beans in terms of moisture content, specific mass, germination, and electrical conductivity for a period of up to 120 days.

Qualidade de grãos de feijão crioulo Gurgutuba branco armazenados em silo bolsa e garrafa pet

Resumo

O armazenamento hermético em silo do tipo bolsa de grãos tem se destacado como alternativa viável ao nível de propriedade rural. Este trabalho teve por objetivo avaliar o uso de silo do tipo bolsa como alternativa no armazenamento de grãos de feijão crioulo. O Experimento foi conduzido no Laboratório de sementes da UFAC, os grãos foram armazenados em silo do tipo bolsa durante 30, 60, 90 e 120 dias. Adicionalmente, foram armazenados em garrafas pet, prática usual. No tratamento controle utilizaram-se de garrafas pet fechadas com tecido organza. O modelo experimental foi DIC fatorial com parcelas subdivididas, com quatro repetições, sendo as parcelas condições de armazenamento e subparcelas períodos de armazenamento. Avaliou-se grau de infestação, teor de água, massa específica aparente, percentual de germinação e condutividade elétrica, em intervalos de 30 dias. Houve variação significativa ($p<0,05$) entre os tipos de armazenamento. Ocorreu a infestação por *Zabrotes subfasciatus* (Boheman) e *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae, Bruchidae). A infestação por estes bruchídeos foram inferiores a 7% em grãos armazenados em silo tipo bolsa e garrafa pet. No tratamento controle, o grau de infestação aumentou significativamente ($p<0,05$), com índices acima de 90% ao fim de 120 dias. O teor de água, massa específica, germinação e condutividade elétrica, dos grãos armazenados em silo do tipo bolsa e garrafa pet preservou as características analisadas durante os 120 dias, com exceção do tratamento controle. O armazenamento em silo do tipo bolsa é uma alternativa eficaz no controle da infestação e na manutenção da qualidade do teor de água, massa específica, germinação e condutividade elétrica, até 120 dias.

Palavras-chave: *Phaseolus vulgaris* L. Atmosfera modificada. Hermético. Infestação.

References

BARONI, G. D.; BENEDETI, P. H.; SEIDEL, D. J. Cenários prospectivos da produção e armazenagem de grãos no Brasil. **Revista Thema,** v. 14, n. 4, p. 55-64, 2017. Disponível em: < DOI: http://dx.doi.org/10.15536/thema.14.2017.55-64.452>

BOHNER, T. O. L.; ARAÚJO, L. E. B.; NISHIJIMA, T. O. Impacto ambiental do uso de agrotóxicos no meio ambiente e na saúde dos trabalhadores rurais. **Revista Eletrônica do Curso de Direito**, v. 8, edição especial, p. 329-341, 2013. Disponível em: <DOI: http://dx.doi.org/10.5902/198136948280>

BRAGANTINI, C. **Alguns aspectos do armazenamento de sementes e grãos de Feijão**. Santo Antônio de Goiás. Embrapa Arroz e Feijão. 2005. 28 p.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento – MAPA. **Instrução Normativa nº 45**, de 21 de setembro de 2013. Anexo XI - Padrões para produção e comercialização de sementes de feijão. (Phaseolus vulgaris L.). Disponível em: http://www.lex.com.Br/legis_24861657_InstruçãoNormativa_N_45_DE_17_de setembro_de_2013.aspx. Acesso em: 15 março de 2019.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento (MAPA). Secretaria de Defesa Agropecuária (ACS). **Regras para análise de sementes (RAS)**. Brasília: MAPA, 2009.399 p.

CASSOL, F. D. R. **Características agronômicas, nutricionais e tecnológicas de grãos de feijão carioca armazenados, cultivados em sistemas orgânico e convencional**. 2017. 112 f. Tese (Doutorado) Programa de Pós-Graduação em Engenharia Agrícola – Universidade Estadual do Oeste do Paraná, Campus de Cascavel, Cascavel, 2017.

COCHRAN, W. G.; COX, G. M. (1968**). Experimental Designs**. 2 ed. New York: Wiley, 1957. 611 p.

COELHO, C. M. M.; MOTA, M. R.; SOUZA, C. A.; MIQUELLUTI, D. J. Potencial fisiológico em sementes de cultivares de feijão crioulo (*Phaseolus vulgaris* L.). **Revista Brasileira de Sementes**, Londrina, v. 32, n. 3, p. 097-105, set. 2010.

COSTA, A. R. da.; FARONI L. R.; D'ANTONINO.; ALENCAR E. R. de; CARVALHO, M. C. S.; FERREIRA, L. G. Qualidade de grãos de milho armazenados em silos bolsa. **Revista Ciência Agronômica**, v. 41, n. 2, p. 200-207, abr-jun, 2010.

JESUS, F. F. de; DE SOUZA, R. T.; DA SILVA, T. G. C.; TEIXIERA, I. R.; DEVILLA, I. A. Propriedade físicas de sementes de feijão em função dos teores de água. **Revista Engenharia na Agricultura**, v. 21, n. 1, p. 09-18, jan./fev. 2013.

LIMA JÚNIOR, A. F. de; OLIVEIRA, I. P. de; ROSA, S. R. A. da; SILVA, A. J. da; MORAIS, M. M. de. Controle de pragas de grãos armazenados: uso e aplicação de fosfetos. **Revista Eletrônica Faculdade Montes Belos**, v. 5, n. 4, 2012.

LANARO, N. di; BAJAY, L. G.; QUEIROZ, V. M. P.; PINTO, R. C. S.; ALBUQUERQUE, L. I. G. de; LESSIO, B. C.; AUGUSTO, P. E. D. Determinação de propriedades físicas do feijão fradinho. **Revista Brasileira de produtos Agroindustriais**, v. 13, n. 1, p. 27-35, abr. 2011.

ELIAS, H. T.; VIDIGAL, M. C. G.; GONELA, A.; VOGT, G. A. Variabilidade genética em germoplasma tradicional de feijão preto em Santa catarina. **Pesquisa Agropecuária Brasileira,** v. 42, n. 10, p. 1443-1449, 2007.

FARONI, L. R. A.; SOUSA, A. H. Aspectos biológicos e taxonômicos dos principais insetos-praga de produtos armazenados. In: ALMEIDA, F. A. C.; DUARTE, M. E. M.; MATA, M. E. R. M. C. **Tecnologia de Armazenagem em sementes**, Campina Grande, 2006. p. 371-402.

FERREIRA, D. F. Sisvar: a Guide for its Bootstrap procedures in multiple comparisons. **Ciência agrotecnologia**, v. 38, n. 2, p. 109-112, mar./abr. 2014.

FREITAS, R. S. **Qualidade de grãos de feijão armazenados sob atmosfera modificada**. 2009. 58 f. Dissertação (Mestre em Agronomia: Fitotecnia) Universidade Federal Rural do Semi-Árido, Mossoró-RN.

MARCHER, E. J. **Sistema Silo-Bolsa.** Disponivel em: <www.marcher.com.br/silo-bolsa/graos>. Acesso em: 11 de fev. de 2020.

MARCOS FILHO, J. **Fisiologia de sementes de plantas cultivadas**. Piracicaba: Fealq, 2005. 495 p.

MICHELS, A. F.; SOUZA, C.A.; COELHO, C. M. M.; ZILIO, M. Qualidade fisiológica de sementes de feijão crioulo produzidas no oeste e planalto catarinense. **Revista Ciência Agronômica**, v. 45, n. 3, p. 620-632, jul.-set, 2014.

MATTAR, E. P. L.; OLIVEIRA, E. de; NAGY, A. C. G.; ARAÚJO, M. L.; JESUS, J. C. S. de; SIVIERO, A. **Descrição de cultivares crioulos cultivados no vale do Juruá**. Embrapa Acre - Livro Técnico (INFOTECA) (2016).

MUTUNGI, C.; AFFOGNON, H.D.; NJOROGE, A.W.; MANONO, J.; BARIBUTSA, D.; MURDOCK, L.L. Triple-layer plastic bags protect dry common beans (*Phaseolus vulgaris*) against damage by *Acanthoscelides obtectus* (*Coleoptera: Chrysomelidae)* during storage. **Journal of Economic Entomology**, Oxford, v. 108, n. 5, p. 2479–2488, oct. 2015.

NAVARRO, S. Advanced grain storage methods for quality preservation and insect control based on aerated or hermetic storage and IPM. **Journal Agricultural Engineering**, v. 49, n. 1, p. 13-20, Jan. 2012a.

NAVARRO, S. The use of modified and controlled atmospheres for the disinfestation of stored products. **Journal of Pest Science**, v. 85, n. 3, p. 301-322, dec. 2012b.

NJOROGE, A. W.; AFFOGNON, H. D.; MUTUNGI, C. M.; MANONO, J.; LAMUKA, P.O.; MURDOCK, L. L. Triple bag hermetic storage delivers a lethal punch to *Prostephanus truncatus* (Horn) (*Coleoptera: Bostrichidae*) in stored maize. **Journal Stored Products Research.** v. 58, n. 3, p. 12-19. July 2014.

NOGUEIRA, R. M.; HERRERA, B. B.; RUFFATO, S.; PIRES, E. M. Simulação e validação de um modelo matemático para o perfil de temperatura do milho armazenado em silo-bolsa. **Cientifica**, v. 42, n. 4, p. 330-337, jun. 2014.

PEREIRA, A. M.; FARONI, L. R. D. A.; SOUSA, A. H.; URRUCHI, W. I.; ROMA, R. C. C. Efeito imediato e latente da fumigação com ozônio na qualidade dos grãos de milho. **Revista Brasileira de Armazenamento**, v. 32, n. 2, p. 100-110, dez. 2007.

RODRÍGUEZ, J. C.; BARTOSIK, R. E.; MALINARICH H. D.; EXILART, J. P.; NOLASCO, M. E. **Almacenaje de granos en bolsas plásticas**: sistema silobag. Disponível em: <https://www.engormix.com/agricultura/articulos/almacenaje-de-granos-en-bolsas-plasticas-t26448.htm>. Acesso em: 12 de mar. 2019.

SANTOS, W. D. dos; CHAVAGLIA, R. F. A importância do controle de armazenagem para conservação e comercialização de grãos. **Revista Científica do Centro de Ensino Superior Almeida Rodrigues**, FAR/ISEAR, Ano 5, nº 5, jan. 2017.

SCHNEIDER, C. F.; MALAVASI, M. M.; TOLEDO, M. V.; STANGARLIN, J. R.; MALAVASI, U. C. Armazenamento de sementes de feijão submetidas a tratamentos sanitários alternativos. **Revista Verde**, v. 9, n. 4, p. 278 - 283, out-dez, 2014.

SHAPIRO, S. S.; WILK, M. B. An analysis of variance test for normality (complete samples). **Biometrika**, v. 52, n. 3-4, p. 591-611, 1965.

SILVA, J. F.; MELO, B. A. DE; LEITE, D. T.; ALMEIDA, F. DE A. C.; PESSOA, E. B. Dados biológicos de Zabrotes subfasciatus (Bohemann, 1833)(Coleoptera: Bruchidae) em dois genótipos de Phaseolus vulgaris L**. Revista Verde**, v. 8, n. 3, p. 06-09, jul-set, 2013.

SILVA, M. G.; SILVA, G. N.; SOUSA, A. H.; FREITAS, R. S.; SILVA, M. S.; ABREU, A. O. Hermetic storage as an alternative for controlling Callosobruchus maculatus (Coleoptera: Chrysomelidae) and preserving the quality of cowpeas. **Journal of stored products research**, v. 78, p. 27-31, set, 2018.

SOARES JÚNIOR, M. S.; CALIARI M.; BECKER F. S.; SOUZA, E. R. B.; VERA, R. Propriedades físicas e químicas de grãos de feijões crioulos vermelhos. **Revista Caatinga**, v. 28, n. 1, p. 263 – 269, jan-mar, 2015.

SPSS. **Sigma Plot user's guide**, Version 10.0. Chicago: SPSS, 2006.

TUKEY, J. W. Comparing individual means in the analysis of variance. **International Biometric Society**, v. 5, n. 2, p. 99-114, 1949.

VIEIRA, R. D.; CARVALHO, N. M. **Testes de vigor em sementes**. Jaboticabal: FUNEP, 1994. 164 p.

WANDER, A. E.; CASTRO, E. de C. Cadeia de produção de sementes de feijão no brasil analisada sob a ótica da nova economia institucional. **Cadernos de Ciência & Tecnologia**, v. 31, n. 3, p. 475-492, set./dez. 2014.

WACHTER, S. A.; PEREIRA, F. de A. R. Custo de armazenagem de grãos no sistema Silos bolsa. **Comunicação & Mercado/Unigran**, v. 4, n. 9, p. 245-253, jan-jun/2015.

ZAMBIASI, C. A. **Qualidade de grãos de feijão armazenados em diferentes condições de temperatura**. 2015. 77 f. Tese (Doutorado Engenharia Agrícola) - Universidade Federal de Viçosa, Viçosa, MG, 2015.

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