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AIR-TIGHTNESS LEVEL IN HERMETIC PLASTIC BAGS (SILO-BAGS) FOR DIFFERENT STORAGE CONDITIONS

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ABSTRACT

The silo-bag is a hermetic storage system used in more than 50 countries. As in any other hermetic storage system, achieving and maintaining a high hermeticity level is a key factor for successful storage.
The air-tightness of the bag can be affected by improper sealing of the end of the bag and perforations in the plastic cover. The evaluation of different sealing techniques and management practices and its effect on the air-tightness level is important for making recommendations for the appropriate use of the silo-bag system.
The objective of this study was to perform a pressure decay test to determine the initial air-tightness level of the silo-bag and its evolution after four months of storage in the field.
The pressure decay test was performed in 23 newly made commercial bags holding approximately 200 tonnes of grain each and was repeated in 13 of these bags after 4 months of storage in the field. In addition to the pressure decay test, soil conditions (bag setup on enhanced soil or setup over residues of the crop), sealing system and presence of ruptures were recorded at the beginning and after 4 months of storage.
In general, a low proportion of silo-bag achieved a good initial half pressure decay time (less than 35%), and in 75% of the bags the half pressure decay time decreased after 4 months of storage. Good sealing practices (especially thermo-sealing) and good soil preparation and good care of the plastic bag correlated with higher hermeticity level. Since the visual inspection is not satisfactory for determining the air-tightness level of a given silo-bag, it is recommended to perform a pressure test before a fumigation, controlled or modified atmosphere treatment.

Key words: modified atmospheres, controlled atmospheres, fumigants application, half pressure decay, pressure drop test, sealing system, ruptures.

INTRODUCTION

The silo-bag is a hermetic storage system used in more than 50 countries. In Argentina 40 million tonnes of grain were stored in silo-bags in 2011 (Bartosik, 2012). Most of the grain stored in silo-bags belongs to farmers. However, the commercial grain industry and grain elevators have shown a growing interest towards this storage system. Only about a 20% of the grain was stored in silo-bags in 2006 (Vicini, 2006) but that proportion has markedly increased from that year.

Each silo-bag is 60 meters long and 2.8 meters in diameter with a plastic cover made of three layers (white outside and black inside) of 235 micrometers thickness (Cardoso et, al., 2008), which has an approximate storage capacity of 180 tonnes of soybean and corn.

The air-tightness created by the plastic of the silo-bag prevents the normal replenishment of oxygen (O_2), a gas used during the aerobic respiration of the biotic components of the bulk (fungi, insects and grain). The plastic also allows the retention of carbon dioxide (CO_2), a by-product gas generated during the respiratory process (Cardoso et al., 2008).

As in any other hermetic storage system, achieving and maintaining proper levels of air-tightness is a key factor for successful storage. Indeed, achieving high levels or air-tightness is critical for effective application of modified atmospheres, controlled atmospheres (Navarro, 1998), and control of biological activity (Darby and Caddick, 2007).

The air-tightness of the silo-bag can be negatively affected by improper sealing of the end of silo-bag and perforations in the plastic cover (Cardoso et al., 2010; Bartosik, 2012). The evaluation of different sealing techniques and management practices and their effects on the air-tightness level is important for making recommendations for the appropriate use of the silo-bag system.

The use of constant pressure test (or pressure drop test) is cited by Navarro (1998) as a valid methodology for determining the level of air-tightness of a storage structure. Darby and Caddick (2007) indicate that the pressure drop test (PDT) is relatively simple and fast.

The objective of this study was to perform a PDT to determine the initial air-tightness level of the silo-bag and its evolution after four months of storage in the field.

MATERIALS AND METHODS

The experiments were carried out in different farms and grain elevators of Balcarce area (Buenos Aires province, Argentine) and Manhattan area (Kansas, USA). The PDT was performed in 23 newly made commercial silo-bags holding approximately 200 tonnes of grain each, and was repeated in 13 of these bags after 4 months of storage in the field.

The procedure for performing the PDT consisted in generating 1200 Pa of negative pressure in the silo-bag. A PVC tube of 50 mm diameter and 1.6 m long was inserted in the silo-bag, close to the center (Figure 1). The inserted end of the tube has a sharp tip made of wood for allowing the penetration of the tube in the grain mass. Several small perforations were made in the tube for allowing the air passage. The other end of the tube came out from the bag and it was used to connect the bag to a vacuum generator connected by a flexible hose. In between the perforated insertion tube and the flexible hose a PVC closure valve was installed.

The vacuum generator in Balcarce was a centrifugal fan (Chicago Blower, 0.33 HP); in Manhattan a Dual Seal Vacuum Pump (General Electric, 1/2 HP) was used. The suction tube was sealed with tape and silicon sealant. The vacuum generator was turned on to generate -1200 Pa, measured with a digital manometer (Sper Scientific, China), and a water column manometer.

The valve was closed at -1200 Pa, or when pressure was constant at values lower than -1200 Pa for 10 minutes, when bags leaked. Time was recorded until pressure dropped to -100 Pa. Soil conditions (i.e., bag setup on enhanced soil or setup over residues of the previous crop), sealing system and presence of ruptures were recorded at the beginning and every 15 days during storage.

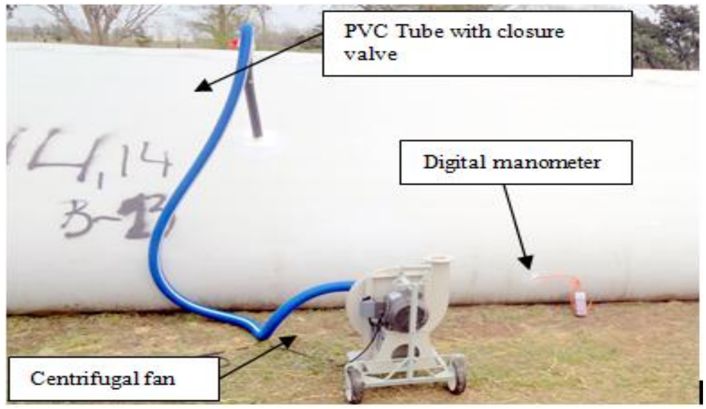

Fig. 1- Instruments used to carry out the pressure test in Balcarce.

From visual observations, two classifications for the bag closing quality were: 1) good sealing system (GSS) or 2) poor sealing system (PSS). Also, two levels of visual classifications regarding rupture risk of bag surface conditions were established: 1) low risk of rupture (LRR) and 2) moderate-high risk of rupture (HRR).

RESULTS AND DISCUSSION

Figure 2 shows silo-bags with good conditions regarding sealing (GSS) and ruptures (LRR) at the beginning of storage. Except for B8, all silo-bags in Fig. 2 were located in grain elevators. Silo-bags with poor sealing (PSS) and / or problems in their plastic cover (HRR) presented in Figure 3 were located on farms. One reason for better conditions at elevators is they dedicate the same site for silo-bags every year, which allows for better soil conditions (leveled, clean, etc) and other practices that favor silo-bag hermeticity. Also, the bag filling operator has better closure technology (i.e., closure tables or thermo-sealing). Contrastingly, when grain bagging is made on farms during harvest, silo-bags are usually placed on land with previous crop residues (sometimes it can be triturated, as in B8 and B16) or on land with flooding risk. Additionally, the sealing operation is implemented without proper care. Thus, simultaneous harvesting and bagging on farms result in more improvised locations and sealing of silo-bags than in grain elevators.

Figures 2 and 3 show that approximately 43% of silo-bags tested reached -1200 Pa during PDT; 63% of silo-bags which reached -1200 Pa were in GSS and LRR conditions (Figure 2). This clearly indicates the positive effect that good sealing techniques, proper soil conditions, and maintenance of the physical structure of the silo-bag have over its air-tightness level.

Darby and Caddick (2007) performed PDT in silo-bags, with range of half pressure decay (HPD) from -1200 to -600 Pa, indicating that a HPD of 5 minutes implies high level air tightness, a HPD of 3 to 5 minutes allows successful fumigation, and a HPD of less than 3 minutes indicates a poor air tightness level. Figure 2 shows that 4 of 11 silo-bags (36%) of the present study rated GSS and LRR, had a HPD (-1200 to -600 Pa) equal to or greater than 5 minutes (4 bags held 600 Pa after 300 seconds), and 5 out of 11 silo-bags (45%) had a HPD of approximate 3 minutes or better (5 bags held 600 Pa after 180 seconds). The rest of the silo-bag in this condition failed the HPD time required for performing a successful fumigation. Darby and Caddick (2007) reported that some recently made silo-bags with no visual evidence of damage or bad sealing had an unsuccessful PDT. This was due to perforations in the bottom of the silo-bag during the bagging operation. A similar conclusion was made from the present study.

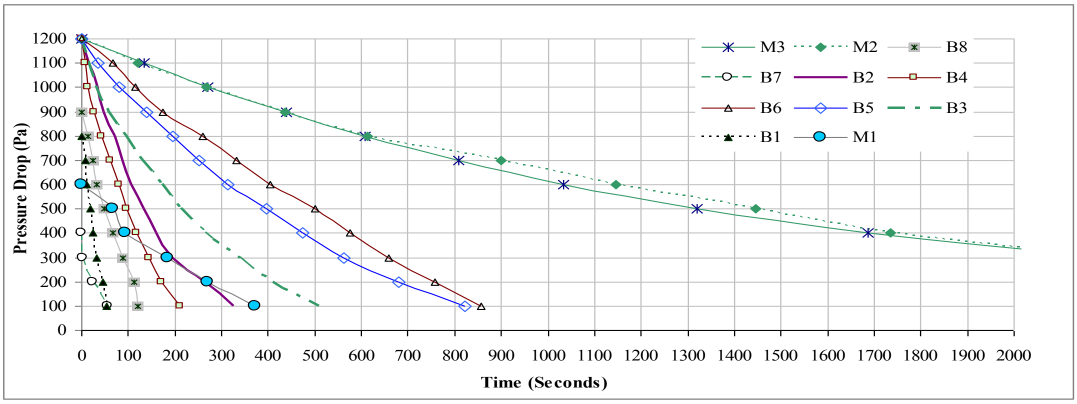

Fig. 2- Pressure drop (Pa) over time (seconds) for silo-bags (M = Manhattan, B = Balcarce) good sealing system (GSS) and low risk of rupture (LRR) at beginning of storage.

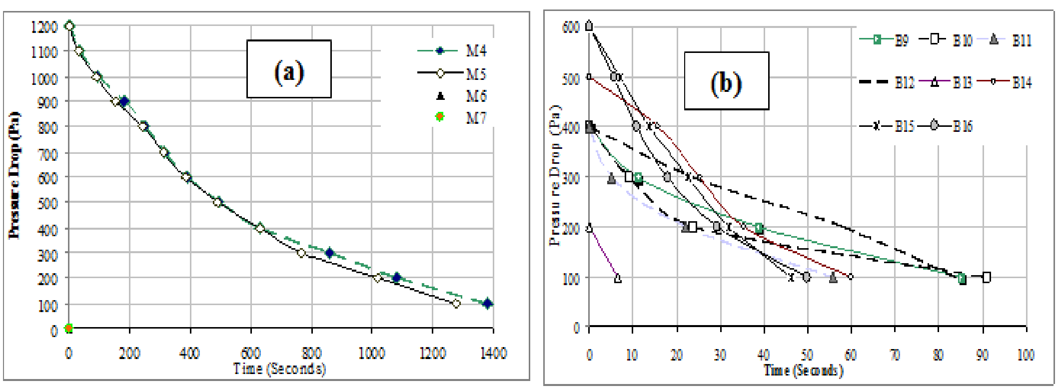

Fig. 3- Pressure drop (Pa) over time (seconds) for silo-bags (M = Manhattan, B = Balcarce) with moderate-high rupture risk (HRR) and: good sealing conditions (a) or poor sealing conditions (b).

Figure 3b shows that no silo-bags rated as PSS reached -1200 Pa. This indicates that closure system is critical for achieving high airtight levels. Figure 3a shows that 50% of silo-bags with GSS reached a PDT of 5 minutes or more, indicating that good sealing system produces a high airtight level. But, the other half did not reach -100 Pa.

Navarro (1998) proposed lower pressures; he performed PDT with HPD from -250 to -125 Pa. His HPD recommendations was that flexible structures of less than 500 m^3 (a silo-bag is 260-270 m^3) require a minimum of 1.5 minutes for efficient use of fumigants, 3 minutes for controlled atmospheres systems and 5 minutes for modified atmosphere systems, including hermetic storage. According to these HPD thresholds, 3 out of 23 (13%) silo-bags classified as an airtight storage system (HPD pressure range of -200 to -100 Pa). Four silo-bags (17%) could be used for controlled atmosphere (HPD larger than 3 minutes), and 8 silo-bags (35%) could be used for successful fumigation (HPD larger than 1.5 minutes). This implies that the typical conditions of silo-bag storage have restrictions on the use of fumigants and, even more, controlled and modified atmospheres. However, there are precedents of successful fumigation (Cardoso et, al., 2009; Ridley et, al., 2011) and even implementation of controlled atmospheres in silo-bags (Milanesio, 2010) at the farm level when GSS and LRR conditions are achieved.

The range of pressure drop considered for computing the HPD test could cause differences in the characterization of the air-tightness level of the silo-bag. For instance, in silo-bag B5 (figure 2) the PDT was of 5:23 minutes when a HPD range of -1200 to -600 Pa was considered, and of 2:20 minutes for a -200 to -100 Pa HPD range. In general, when a lower range of pressure drop is used, HPD time is lower. The variation of HPD time according to the pressure range is more significant in those bags with high HPD. An over or underestimation of the air-tightness level of the silo-bag could be made according to the range of HPD test implemented..

Figure 4 shows that in 75% of the silo-bags, HPD time, and thus hermeticity, decreases after 4 months of storage (study only includes Balcarce silo-bags). Some silo-bags could not achieve the target pressure of -200 Pa. Darby and Caddick (2007) reported that maintaining tightness in silo-bags required continuous maintenance. In most cases, the loss of tightness was related to ruptures caused by animal (foxes, dogs, birds, rodents, etc) on the plastic covers. These problems are more common at the farm level than at the grain elevators. The use of electric fences to keep animals out of the silo-bag area was a suitable solution. In some silo-bags, HPD decreased substantially but no evidence of bag damage was observed. Surprisingly, the hermeticity of one silo-bag at the end of storage was greater than at the beginning. This is explained by the development of vegetation under the silo-bag that sealed ruptures in the bag floor, increasing the air-tightness.

Since visual inspection is not satisfactory for determining air-tightness of a given silo-bag, it is recommended that HDP tests be made before a fumigation or controlled or modified atmosphere treatment.

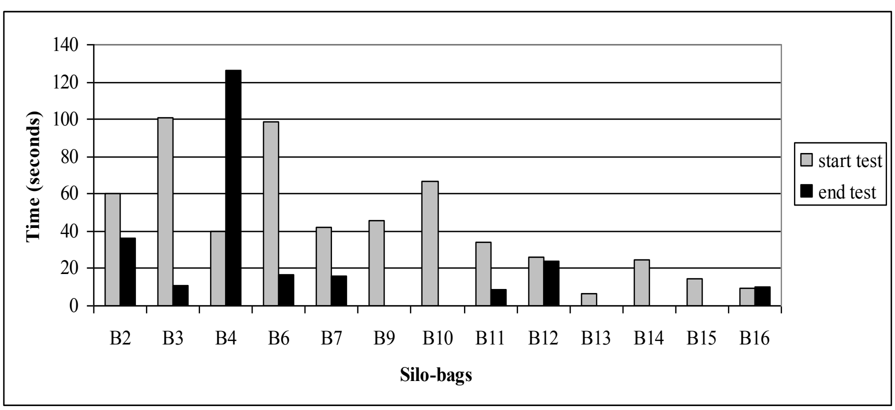

Fig. 4- Time (seconds) of half pressure drop (from 200-100 Pa) for 13 silo-bags in start an end test.

Results from Figure 5 indicate that any fumigation, controlled or modified atmosphere treatment will have better success at the beginning of storage than after several months. Since the plastic cover of the silo-bag prevents the entrance of insects, once the bag was treated, few chances of re infestation should be expected.

CONCLUSIONS

Pressure decay test were performed in several silo-bags, with the results related to the sealing and plastic cover conditions.

The pressure decay test was simple and its implementation was not problematic, either at the elevator or farm.

In general, a low proportion of silo-bag achieved a good initial half pressure decay (HPD) time (less than 35%); in 75% of the bags the HPD time decreased after 4 months of storage.

Good sealing practices (especially thermo sealing) and good soil preparation and good care of the plastic bag correlated with higher hermeticity level.

The pressure range at which the HPD test is performed affected the test result.

Fumigation, controlled or modified atmosphere treatments will have more chances to be successful at the beginning of storage than after several months.

Since the visual inspection is not satisfactory for determining the air tightness level of a given silo-bag, it is recommended to perform an HDP test before a fumigation, controlled or modified atmosphere treatment.

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