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Hermetic storage of wet corn in liners with and without ethylene vinyl alcohol (EVOH) barrier

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ABSTRACT

Due to cold and wet weather conditions during autumn, corn (*Zea mays* L.) has to be harvested wet in many regions of Argentina. Most farms do not have grain dryers and they store wet corn in silo bags for 2 to 9 months. Storage of wet grain leads to quality loss due to biological activity which, to some extent, is reduced by the modified atmosphere generated. Hence an experiment was conducted to investigate the incorporation of an oxygen (O_2) barrier (Barrier) in the plastic liner (EVAL ™, EVOH, Kuraray) on the degree of modification of the interstitial atmosphere and its benefit in preserving quality parameters of wet corn in comparison with the standard silo bag plastic liners (Standard). The results show that the bags with Barrier resulted in a greater modification of the interstitial atmosphere and that quality parameters were, in general, less affected than in the Standard bags. The incorporation of O_2 barriers to plastic liners could be a cost effective technology for improving hermetic storage conditions of quality grain or seeds.

Key words: Grain quality, Hermetic, Seeds, Silo bag, Viability

In many corn growing regions of Argentina and other countries, during autumn, ambient temperature decreases and relative humidity increases, reducing the drying potential of the air. Under this condition, corn (*Zea mays* L.) often cannot be dried in the field before winter and has to be harvested wet. At the farm level, there is insufficient artificial drying capacity and a silobag, a potentially hermetic storage system widely used in Argentina (Bartosik, 2012), is frequently used for storing wet corn. After a storage time from 2 to 9 months, this corn is used as feed for beef, poultry, eggs or pig production on the same farm, or can be sold as grain in the commercial market, if commercial quality parameters are not affected. However, storage of wet corn results in higher biological activity and greater quality reduction than the storage of dry corn. Farmers are more aware of the detrimental effects on commercial quality than on other quality parameters, such as nutritional value or sanitation problems (e.g. mycotoxins).

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Hermetic storage creates a modification of the interstitial atmosphere due to the respiration of the biotic components (grain, fungi, insects, etc.) which results in a decrease in the O_2 concentration and an increase in the CO_2 concentration. This modification of the internal atmosphere results in a reduction of the biological activity and better preservation of the stored product (Navarro et al., 2012). It has been reported that germination test, grain damaged by mold, test weight and fungal colony forming units, among others, were used to evaluate storage conditions (Weinberg et al., 2008; Cardoso et al., 2010; Gregori et al., 2013).

The standard silobag is made of a three layer mix of low density and high density polyethylene liner, 230 micrometer thick. The resistance to the O_2 and CO_2 permeability through the liner matrix could be increased by incorporating a thin barrier of Ethylene vinyl alcohol (EVOH). The incorporation of EVOH to the plastic liner could result in a greater modification in the interstitial atmosphere and better preservation of the quality parameters of grain and other products.

Besides silo bags, hermetic storage with flexible liners are being used, or are under evaluation, for storing specialty grain in small bags (20–50 kg), jumbo bags (500–1,000 kg) and even bigger bags (50,000 kg). This research is on-going but it is expected that liners with O_2 barriers would substantially improve their storage conditions.

The purpose of this research was to compare, in a small scale experiment, the hermetic storage of wet corn in Standard plastic bags with the storage in bags with gas Barrier (EVAL^{TM}, EVOH, Kuraray) in terms of internal atmosphere composition and grain quality parameter preservation.

MATERIALS AND METHODS

Plastic bags of 0.4 m wide, 0.3 m deep and 0.7 m tall, holding 50 kg grain, were made with a thermo-sealing device. The bags were made with two different types of liners: 230 μm thick (Standard silo bag liner) and 150 μm thick with EVOH Barrier (EVAL ^{TM}, Kuraray).

Fresh corn from the 2014 harvest was collected from a local farm with average moisture content (m.c.) of 16% and immediately bagged and thermo-sealed. The bags were placed in a temperature controlled room at 20°C during 270 days. The gastightness of the bags was evaluated with a pressure decay test (PDT). A vacuum pump (pressure: 3 kg/cm^2 – flow: 40 l/minute) was connected to the bag until a negative pressure of –250 Pa (Sper Scientific, 840082, USA) was generated. Then, the time at which the negative pressure decreased to half the initial value (–125 Pa) was recorded and the bag was rated as 'sealed' (PDT >5 min) or 'unsealed' (PDT <5 min) according the recommendation of Navarro (1999) for airtight storage. If the test result was lower than 5 min, bag was re-sealed and the PDT repeated (Fig. 1).

Temperature and relative humidity data from one bag from each plastic cover were recorded every three hours with a datalogger (Ibutton, Hygrochrom,

Fig.1. Performing a pressure decay test in the experimental bags

EEUU). Concentrations of CO_2 and O_2 were measured every week with a portable gas analyzer (Checkpoint, Dansensor, Denmark) (Fig. 2), while quality tests were performed at the beginning of the study, and at 60, 120, 180 and 270 days. The quality evaluation included germination test (ISTA, 2008), mold damaged kernels and test weight (SAGyP, 1994), fungi colony forming units (CFU) (Put, 1974). In the bags corresponding to T_1 (60 days) and T_2 (120 days), a cage containing

Fig. 2. Measuring O_2 and CO_2 concentrations

Fig. 3. Insect counting (*Sitophilus oryzae)* and cages with grain and insects (*right*)

30 live adults of rice weevils (*Sitophilus oryzae*) were incorporated and insect count was done at the opening time (Fig. 3). Corn samples were evaluated by HPLC for aflatoxins, fumonisins, zearalenones and ochratoxins at the beginning and at the end of storage (270 days) at the Fundación de Investigaciones Científicas Teresa Benedicta de la Cruz (Lujan, província de Buenos Aires, Argentina).

RESULTS AND DISCUSSION

The average temperature during storage was between 18° and 20°C, and relative humidity (r.h.) in the interstitial grain mass between 77 and 79% (Table 1). This r.h. indicates that the water activity was high enough to support mold growth during storage (Jayas et al., 1994).

Results indicated that liners with Barrier initially resulted in a slightly lower O_2 concentration than the Standard liners and the reduction of the O_2 concentration to the minimum level was reached earlier. Additionally, the CO_2 concentration was higher in the bags with Barrier liners than in the Standard liner bags. The O_2 concentration in the bags with Barrier dropped to 1.4% in 56 days, while in the Standard bags the same concentration was achieved one week later. Though a great effort was made to achieve a perfect seal of the experimental bags, it is possible that airtightness was somehow compromised during the subsequent handling of the bags. This could be the reason of the increase in O_2 concentrations during the remaining storage time and indicates that achieving and maintaining a good sealing of the bags is critical for incorporating barrier technology in plastic liners. The CO_2 concentration in the liners with Barrier reached 15% in 56 days, but only 8% in the Standard liners for the same storage period.

As a result of the higher degree of modification of the interstitial air, the preservation of the quality parameters of the grain stored in liners with Barrier outperformed the storage in Standard liners. Germination test was a good indicator of quality. It dropped during the first 60 days of storage from 95% to 81% under Barrier treatments and 75% for

Table 1 Average temperature and relative humidity for the two treatments during the entire storage

Treatment	Temperature (°C)	r.h. (%)
Standard	20.4	77
Barrier	18.0	79

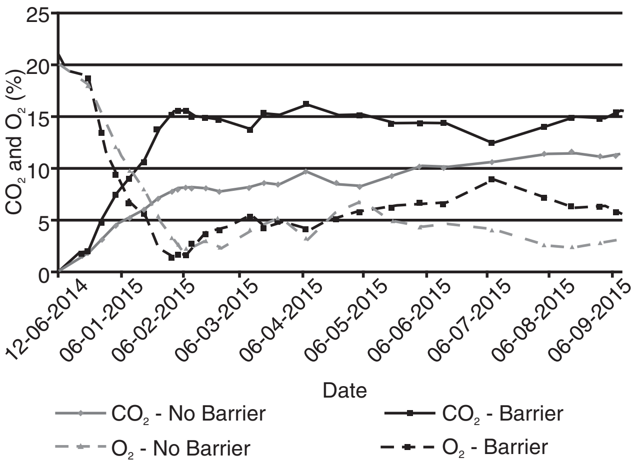

Fig. 4. CO_2 and O_2 concentration (average of three replicates) for bags with Barrier and Standard (no Barrier)

Table 2 Quality parameter during storage for standard bag and barrier bag

Parameter	Treatment	Day 0	Day 60	Day 120	Day 150	Day 180
Germination test (%)	Standard	95	81	48	23	38
	Barrier	95	75	72	61	68
Mould damaged kernels (%)	Standard	0.5	0.9	0.7	0.9	1.0
	Barrier	0.8	0.7	0.6	0.8	0.8
Test weight (kg/100 l)	Standard	76.2	76.4	74.8	75.3	74.7
	Barrier	75.7	76.7	75.6	75.4	75.8
CFU (log 10)	Standard	4.9	6.5	4.3	4.8	4.7
	Barrier	4.5	6.5	4.3	4.5	4.5
Live insect count	Standard	30	75	10	-	-
	Barrier	30	5	0	-	-

Standard treatments. After 60 days, Barrier liners always had substantially higher values of germination than Standard and, by the end of storage (270 days), the Barrier bags maintained a germination above 60%, while in the Standard bags it dropped below 40%. Although the moisture content of the corn in this experiment (16%) was substantially higher than that recommended for corn seed storage (around 12%), these results indicates that the seed industry could incorporate the Barrier technology in the seed bags to better protect the germination during storage.

The mold damaged kernels percentage remained stable around 1% in the bags with Barrier and increased to 1.5% in the Standard bags and the test weight resulted about 1 point higher in the bags with Barrier.Although the difference among treatments was small, these two parameters indicate that the use of Barrier reduced the biological activity and damage to the grain.

Both liners showed an initial increase in the CFU from 4.5 and 4.9 to 6.5, but when O_2 was reduced (to about 2% after 60 days), CFU decreased to the initial value, implying that microbial activity was affected by the modified atmosphere generated in both liners. Mycotoxins were not detected in any treatment at any sampling time.

Live insect count was reduced from 30 insects at the beginning to 0 after 120 days in the bag with Barrier, while in the Standard bag the count initially increased to 75 at 60 days and then decreased to 10 at 120 days, indicating that the modified atmosphere affected the insect population growth in both treatments, but the effect was higher in the bags with Barrier.

CONCLUSION

This work showed that the use of liners with barriers (EVOH, EVAL, Kuraray) resulted in a modification of the interstitial atmosphere of slightly wet corn (CO_2 more noticeable than O_2) which had advantages in the conservation of germination, a reduction in mould damaged kernels, better test weight and reduced CFU and live insect count during storage.

The incorporation of O_2 barriers to plastic liners could be a cost effective technology for improving hermetic storage conditions of quality grain or seeds.

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