Bartosik R, Ochandio D, Cardoso L, Torre DDL (2012) Storage of malting barley with different moisture contents in hermetic silo-bags. In: Navarro S, Banks HJ, Jayas DS, Bell CH, Noyes RT, Ferizli AG, Emekci M, Isikber AA, Alagusundaram K, [Eds.] Proc 9th. Int. Conf. on Controlled Atmosphere and Fumigation in Stored Products, Antalya, Turkey. 15 – 19 October 2012, ARBER Professional Congress Services, Turkey pp: 549-554

STORAGE OF MALTING BARLEY WITH DIFFERENT MOISTURE CONTENTS IN HERMETIC SILO-BAGS

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ABSTRACT

The storage of dry malting barley (12%) in silo-bags is a well adopted practice in Argentina, with no deleterious effects on the malting process. However, sometimes farmers have to store barley at moisture contents higher than 12%, implying a higher risk for the malting quality and, eventually, a monetary loss for farmers (barley has to be traded as feed). In that sense, it would be convenient to have a monitoring tool that would allow for testing the storage condition of the barley in the silo-bag and making a quick risk assessment. The objective of this study was to quantify the effect of storage moisture content on the germination of barley and to determine its correlation with the CO_2 concentration, as an indicator of storage risk. The tests were carried out in two silo-bags filled with barley at moisture content ranging between 13 and 18%. Grain samples were collected, at the beginning of storage and every 15 days during five months of storage and submitted to the lab for performing the germination test. Carbon dioxide and grain temperature were measured in the silo-bag with the same frequency. For the temperature values registered in summer time in Argentina, it is not safe to store malting barley with moisture over 14%. With moisture content lower than 14%, barley can be stored in silo-bags for 5 months without affecting the germination. Carbon dioxide measurement is an effective indicator for detecting grain spoilage risk caused by excessive moisture content or for detecting potential problems derived from water infiltration in the bag during storage. However, the evolution of CO_2 should be used as a spoilage indicator during storage rather than a single reading at a particular moment.

Key words: grain storage, carbon dioxide, biological activity, germination test, grain temperature.

INTRODUCTION

Argentina is the largest producer of barley in South America, with an estimated production of 4 million tonnes in 2011/2012 (Agrositio, 2012). The main destination of barley is the malting industry. Quality requirements of barley include a germination test (GT) of 98.5% with a tolerance to 95%, grain size, protein content and a low percentage of shelled and broken kernels (Savio and Cattaneo, 2008).

Barley is stored either in permanent storage structures (bins or flat storage) or in silo-bags. The silo-bag is a hermetic storage system with a self-modified atmosphere. The silo-bag plastic cover is made with a three-layer polyethylene of 235 μm thickness which prevents the free exchange of gases between the ambient atmosphere and the interstitial space. Thus, the

bulk biotic respiration (grains, fungi and insects) produces the increase of CO_2 concentration and the reduction of O_2 concentration (Bartosik et al., 2008a).

Some studies on dry barley storage (12% moisture content (m.c.) or less) in silo-bags have been reported (Ochandio et al., 2008; Massigoge et al., 2010). The results showed that commercial quality was not affected after 12 months of storage. On the contrary, storage of barley with higher m.c. negatively affects the malting process due to a drop in germination (Cardoso et al., 2010). In this sense, Darby and Caddick (2007) mentioned that the safe storage time for barley stored in silo-bags at 14% m.c. and 35°C would be reduced to only 1 month.

During rainy years it is common to harvest barley with a m.c. higher than 12.5% (trading tolerance), that must be stored wet in silo-bags for a few months before it is conditioned to the safe storage m.c. This represents a risk of quality loss if the grain remains stored in the silo-bag for a long period of time. Bartosik et al. (2008a) showed that for wheat stored in silo-bag the CO_2 concentration increased with the grain m.c., and that the increase of biological activity in the wet grain can produce commercial quality loss. Massigoge et al. (2010) hypothesized that it would be possible to use the CO_2 concentration to estimate the risk of commercial quality loss for barley stored in silo-bags.

The objective of this study was to quantify the effect of grain m.c. on the germination of barley and to determine its correlation with the CO_2 concentration in the silo-bag as an indicator of spoilage risk.

MATERIALS AND METHODS

The tests were carried out in the district of Balcarce, Buenos Aires province, Argentina. Two silo-bags (A and B) with approximately 180 tonnes of malting barley with m.c. from 12.9 to 17.9% in each bag were selected. Three sampling sites were determined for each silo-bag based on grain m.c. data (high, low and intermediate) obtained from samples collected during the bagging operation (Table 1).

Table 1. Initial moisture content (m.c.) for 3 sampling sites for silo-bags A and B

	Initial m.c. (%)		
	Site 1	Site 2	Site 3
Silo-bag A	A1: 13.8	A2: 13.4	A3: 12.9
Silo-bag B	B1: 17.9	B2: 15.4	B3: 13

The study began on January 13 (15 days after bagging) and lasted about 135 days. Carbon dioxide concentration, grain temperature, m.c. and germination were determined. The sampling procedure consisted of measuring the CO_2 concentration with a portable gas analyzer (PBI Dan Sensor, CheckPoint, Denmark) and perforating the plastic cover with a needle. A wooden stick with three temperature sensors at different heights was inserted into the grain mass (diagonally from top to bottom and towards the center of the silo-bag) for measuring grain temperature at about 0.1, 0.7 and 1.4 m from the surface of the grain. Temperature values were obtained between mid-morning and noon. Later, at each sampling site, a grain sample was collected using a standard torpedo probe, separated in three different levels (0.10, 0.75 and 1.6 m depth, corresponding to the upper, middle, and lower layer, respectively, being the total height of the silo-bag of 1.7 m). After sampling the silo-bag, the openings were sealed with a special tape in order to restore the hermeticity. The described

sampling procedure was repeated approximately every two weeks during the storage period. The collected grain samples were placed in sealed plastic bags and submitted to the Grain Postharvest Laboratory of INTA (Balcarce Research Station), where the grain m.c. was measured with a moisture meter (GAC 2100, Dickey-John), and to the Seed Laboratory where GT was conducted as recommended by ISTA (2008), by pre-chilling the seeds for 48 h and then placing the seeds for germination during 7 days at 20°C under light conditions (four replicates of 50 seeds were considered).

RESULTS AND DISCUSSION

The grain temperature (excluding the peripheral grain layer in the bag) at the beginning of the study (mid-January) was 22°C for both silo-bags (Figures 1 and 2). The maximum temperature was registered at the end of January (24 and 26°C for silo-bags A and B, respectively), then the temperature constantly declined until mid-April (fall). In subsequent samplings it was observed that the temperature stabilized, ending with 16°C in both bags at May 31st. These ranges of temperature and their evolution are consistent with those reported by Ochandio et al. (2009) and Cardoso et al. (2010) for similar locations and storage period.

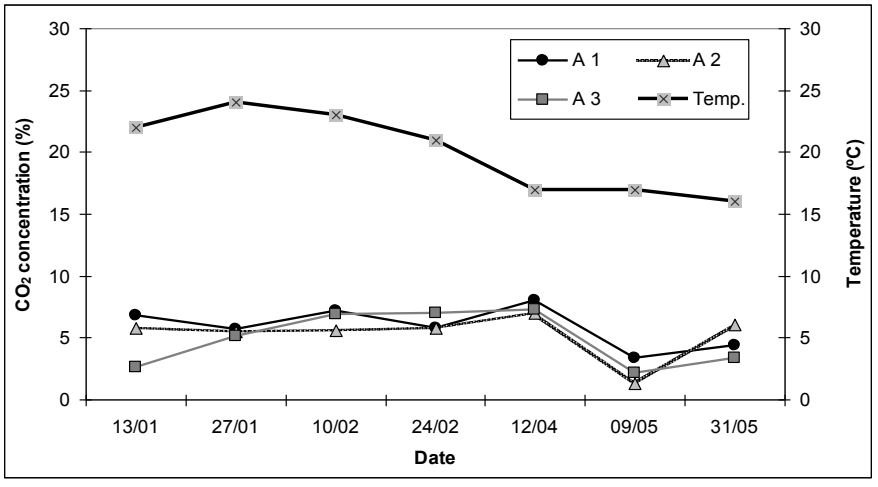

Fig. 1- CO_2 concentration (%) for the three sectors of the silo-bag A (A1, A2 and A3) and temperature (Temp., ºC) of silo-bag A during the storage period.

Figure 3 shows that the germination in the three sectors of silo-bag A (A1, A2 and A3) and sector 3 of silo-bag B (B3) remained clearly above the commercialization tolerance (95%) during the study period.

For the range of grain temperature observed in this study the values of germination are consistent with the recommendations realized by Darby and Caddick (2007), who suggest a safe storage time of 9 and 6 months for barley grain stored with 13 and 14% m.c., respectively (at 25°C or less). These authors also mentioned that with temperature of 35°C and m.c. of 14%, deterioration of quality occurs very quickly.

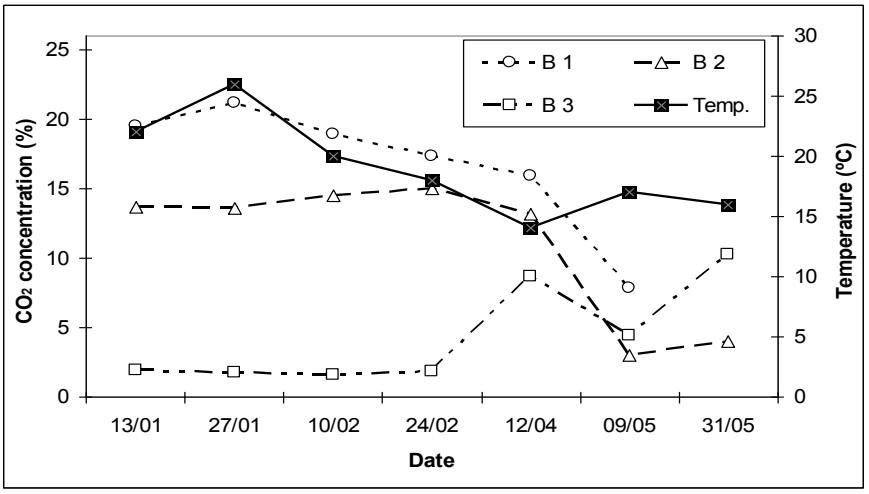

Fig. 2- CO_2 concentration (%) for the three sectors of the silo-bag B (B1, B2 and B3) and temperature (Temp., ºC) during the storage period.

In sectors 1 and 2 of the silo-bag B (B1 and B2), with m.c. of 17.9% and 15.4%, respectively, the values of germination after 15 days of storage was below 98% (Figure 3). During the first month of storage the germination in sector B2 continued the decreasing tendency, but with values still higher than 95%. After February 10th a rapid decrease of germination was observed, falling to 76.1% at end of test. In sector B1 (17.9% m.c.) the germination fell to 30% after the first month of storage. In late February, the germination was lower than 10% in this sector.

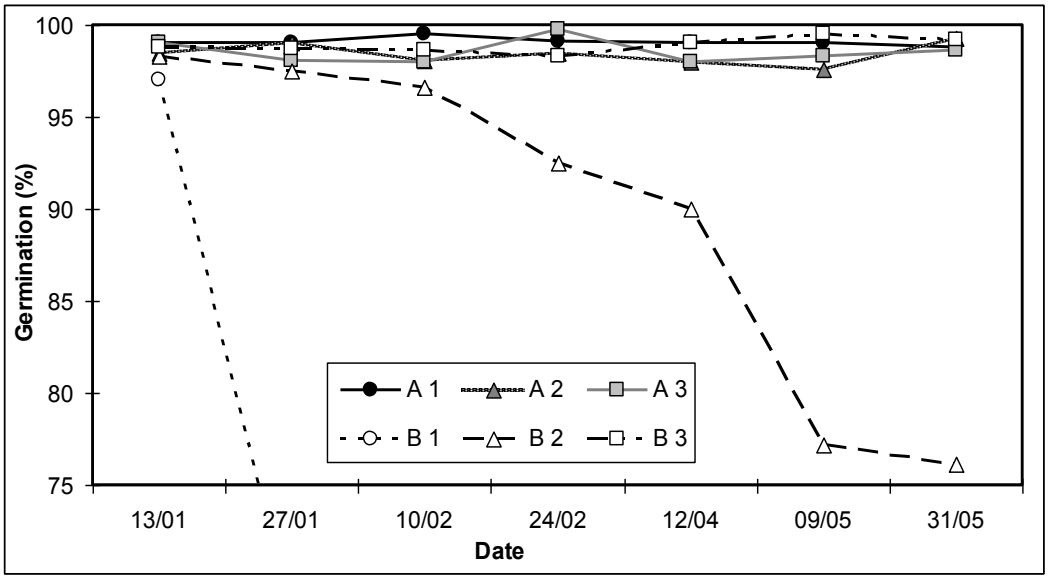

Fig. 3- Germination values for the three sectors of the silo-bag A (A1, A2 and A3) and the silo-bag B (B1, B2 and B3) during the storage period.

There was a positive correlation between CO_2 concentration and grain m.c. When the m.c. was under 13.8% (silo-bag A, and sector 3 of silo-bag B) the CO_2 concentration was about 3-8%. When the grain m.c. was higher, the CO_2 concentration of the silo-bag sector also was higher. For instance, in sector B1, with 17.9% m.c., the CO_2 concentration rose up to 20%, while in sector B2, with 15.4% m.c., the CO_2 was about 15% (Figures 1 and 2). This result is consistent with the results obtained by Crocce (2009) for silo-bags with wheat at different m.c. values.

The maximum CO_2 concentration for each sampling site is reached, in general, during the first month of bagging. In general, biological activity also responded to grain temperature. In the silo-bag, grain temperature is influenced by the ambient temperature throughout the storage season (Bartosik et al., 2008a). Barley is bagged in early summer, so the maximum grain temperature is reached during the first months of storage. During fall, the grain temperature decreased and hence the biological activity. The CO_2 concentration measured in the silo-bag is the result of a balance between the respiration rate (CO_2 production), and the CO_2 lost from the silo-bag by permeability of the system - through openings in the plastic cover or through the natural permeability of the plastic material to the gases. This explains the reduction in the measured CO_2 concentration in May, following a decrease in the grain temperature. The same relationship among grain temperature and CO_2 concentration was reported by Crocce (2009), who observed a decreasing tendency of biological activity during cold season for wheat stored in silo-bags. This tendency was stronger with grain at 13% m.c. or higher.

However, in sector 3 of silo-bag B (B3) there was an increase in the biological activity after February, contrary to the decreasing trend of the grain temperature (Figure 2). The CO_2 concentration increased from 2% to about 10%, implying that the biological activity did not correspond to the grain m.c. (13%). This increase in biological activity could be related to water entering to the system through perforations of the plastic bag, which caused spoilage problems in that sector of the grain mass. The increase of CO_2 in the autumn, due to spoiled grain in the bottom of silo-bag, was also reported by Massigoge et al. (2010) and Cardoso et al. (2010) for dry barley stored in silo-bags.

Bartosik et al. (2008b) suggested that CO_2 monitoring could be used as an early indicator of spoilage problems in silo-bags. In this study, a relationship between CO_2 concentration and grain quality could be established. In sectors B1 and B2 (m.c. of 17.9 and 15.4%, respectively) there was an immediate evidence of biological activity, which resulted with a substantial decrease in the germination. During the entire storage period the CO_2 concentration fluctuated between 20 to 13% in summer, and then decreased to 5 to 10% in fall. On the other hand, the sites in which m.c. was below 14% (A1-A3 and B3) and the CO_2 concentration was from 2 to 7% at the beginning of storage, the germination did not decrease. Furthermore, in the site B3 there was an increase the CO_2 concentration in May (Figure 2), but no negative effect in the germination was observed. It could be hypothesized that the increase in the biological activity could come from a localized spoiled area from water entering through some perforation in the bag, as it was explained before. This localized spoiled grain would generate enough biological activity to affect the CO_2 concentration of the sector, without affecting the germination of the barley. This would indicate that the evolution of the CO_2 concentration rather than isolated readings of CO_2 should be taken into account when CO_2 is used as a storage quality parameter. If only a single CO_2 reading taken in a specific moment is used to estimate storage risk, the storage risk could be over or underestimated.

These results indicate that, for the temperature values registered in summer time in Argentina, it is not safe to store malting barley with m.c. over 14%. With m.c. lower than 14%, barley can be stored in silo-bags for 5 months without affecting the germination.

Carbon dioxide measurement is an effective indicator for detecting grain spoilage risk caused by excesive m.c. or for detecting potential problems derived from water infiltration in the bag during storage. However, the evolution of CO_2 should be used as a spoilage indicator during storage rather than a single reading in particular moment.

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