

Storage of quality malting barley in hermetic plastic bags

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Abstract

The main destination of barley grown in Argentina is malt production. The main standard quality parameter for the malting industry is to maintain at least 98% germination percentage (GP). A typical operation is to harvest dry barley (around 12%) and store it in hermetic plastic bags, a temporary storage system of modified atmosphere, until end use in the malting industry. The objective of this study was to determine whether the typical Argentinean storage condition of malting barley in hermetic plastic bags produces a deleterious effect in its commercial and industrial quality. Two plastic bags filled each with 180 tonnes of malting barley were used for this experiment, one with 11% moisture content (m.c.) and the other with a range between 11 and 11.5% m.c. The experiment began immediately after harvest on December 27th (early summer) and lasted for five months. Carbon dioxide (CO₂) concentration, grain temperature, m.c., protein and GP were evaluated every 2 wk. GP did not substantially decrease during the entire storage period for both bags, but samples with higher m.c. had the lowest GP. The protein percentage remained stable throughout the entire evaluation period for both bags. The maximum value of CO₂ in the bag with 11% m.c. was 4.4%. The bag with the higher range of m.c. had a maximum CO₂ value of 13%, and this high concentration was associated to a small portion of spoiled grain, presumably due to rain water entering the bag through perforations in the plastic cover at the bottom of the bag. It was concluded that it is safe to store quality malting barley with 12% m.c. or less in hermetic plastic bags for five months.

Keywords: Silobag, Grain, CO₂, Germination

1. Introduction

The annual production of barley in Argentina is currently estimated in 2 million tonnes, of which 90% is used for malt production (Cortese, 2009). The malting process requires a high and uniform germination of barley seeds (Savio and Cattaneo, 2008). Consequently, the commercialization standard includes specific parameters for determining the industrial performance of the grain, such as grain size, maximum and minimum protein values (between 11 and 13%) and a high percentage of viability or germination (basis of 98%, tolerance of 95%) (SAGPyA, 2009). The length of the storage period could be critical for some of the barley quality parameters listed above, for example, seed viability, and thus for the performance of the malting process. Moisture content (m.c.) and temperature of grain during storage can affect enzymatic processes for the production of malt (Darby and Caddick, 2007).

In Argentina, barley is stored in bins and flat storage structures by industry and grain elevators 489,000 t, according to the Cámara Industrial de Cervecería Argentina (2007), although a significant fraction of the harvested grain is retained by farmers in temporary storage structures made of hermetic plastic bags (silobags). This is a self-modified atmosphere storage system, with limited exchange of gasses between the interstitial atmosphere and outside atmosphere. Each plastic bag is 60 m long, 2.74 m in diameter and 235 microns thick. Bags are made of a plastic material with three layers, black on the interior and white on the exterior side. Each bag can store about 180 t of barley, soybean or corn.

There are few references to barley storage in plastic bags. Recently, Ochandio, et al. (2009) found good quality preservation of barley (high germination percentage and stable protein content) after 12 months of storage at around 12% m.c. (marketing limit). Darby and Caddick (2007) mentioned that barley stored in plastic bag under Australian conditions, even with 11% m.c. or less, can result in a peripheral layer of damaged grain with general deterioration and loss of quality for malting. Simulation studies calculated an area of 20 cm near the surface of the bag (20% of stored grain) is susceptible to deterioration (Gaston, et

al., 2007) for wheat stored in a plastic bag in the same season as barley. The objective of this study was to determine whether typical Argentine storage conditions in hermetic plastic bags affect industrial and commercial quality of malting barley.

2. Materials and methods

Tests were conducted on a farm “Mitikily”, in the district of Tres Arroyos (Buenos Aires, Argentina). Two plastic bags (A and B) were filled with approximately 180 t of malting barley each. The barley in bag A had about 11.0% m.c., while in bag B it ranged between 11.0 and 11.5% m.c. The experiment began immediately after harvest on December 27th (early summer) and lasted during five months. Carbon dioxide (CO₂) concentration, grain temperature, m.c., protein and germination percentage (GP) were evaluated.

Three sampling locations were established for each plastic bag, the first one at 5 meters from the beginning of the bag (S.I), the second sampling location was at the central part of the bag (S. II) and the third location at 5 m from the end of the bag (S. III). The sampling procedure in each location consisted in measuring the CO₂ concentration with a portable gas analyzer (PBI Dan Sensor, CheckPoint, Denmark), perforating the plastic cover with a needle. A wood stick with three temperature sensors was then inserted into the grain mass (diagonally, from top and side to bottom and center of the silobag) to measure grain temperature at approximately 0.1; 0.7 and 1.4 m from the grain surface. The temperature readings were obtained between mid-morning and noon. Later, in each sampling location, a grain sample was collected using a standard torpedo probe from three different levels (0.10; 0.75 and 1.6 m depth, corresponding to the top, middle and bottom layer, respectively, being the total height of the bag was 1.7 m). Material from each of the three sampling locations was segregated by level (surface, middle, and bottom). The grain samples were stored in sealed plastic bags and brought to the Grain Postharvest Laboratory (GPL) of Balcarce Experimental Station of the National Institute of Agricultural Technologies (INTA) for testing. After probing the plastic bags, the openings were sealed with a special tape in order to restore the air-tightness. The described sampling procedure was repeated approximately every two weeks during the entire storage period.

Grain samples were analyzed for m.c. (GAC 2100, Dickey-John). Protein grain analysis was done by the Kjeldahl method (realized by Maltería Quilmes, Tres Arroyos), as it is regulated by the Argentine barley quality standard (SAGPyA, 2009). Germination testing was carried out following the recommendation of ISTA (2008): pre chilling for 48 h and then placing samples to germinate for 7 d at 20°C in light conditions; there were four 4 replicates of 50 seeds for each level of each sampling site. During extraction of the grain at the end of the storage period the presence of spoiled grain was also documented via visual inspection.

3. Results

Figure 1 shows the average m.c. of each sampling point during storage. The initial m.c. was from 11.5 to 12%. There was a decreasing trend over time of about 0.5% m.c., in all locations. The maximum m.c. standard deviation between layers was 0.26% (Figure 2) and occurred in the third sampling date, and remained below this value during the remainder of the experiment.

The initial GP in both bags was near 100%. In bag A (11% m.c.) the GP were above 98% at the end of the experiment (Figure 3). On the other hand, some locations of the bag B (Fig. 4) it showed a slight decreasing trend. In the S. I site (initial 11.5% m.c.) the GP reached a level of 97.4% at the end of storage. The final GP values in S. II of bag B (11.3% m.c.) was 98.6%, while S.III (11.1% m.c.) finished with a GP of 97.8%.

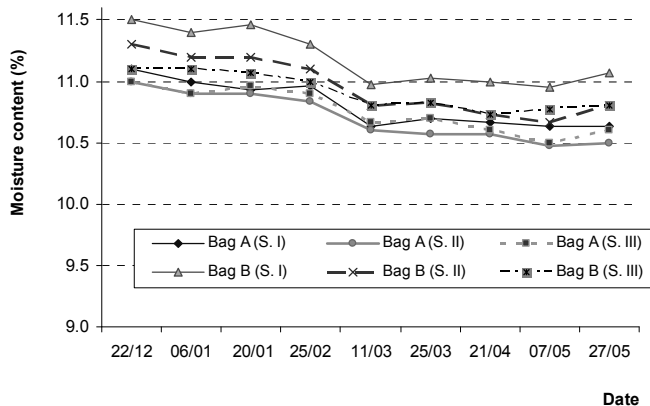


Figure 1 Evolution in time of average moisture content (%) for three sampling points of the A and B bags.

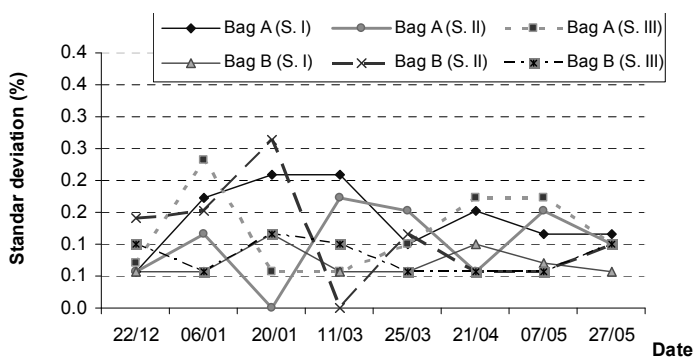


Figure 2 Evolution in time of moisture content standard deviation (%) for three sampling sites (S. I, S. II and S. III) of A and B bags.

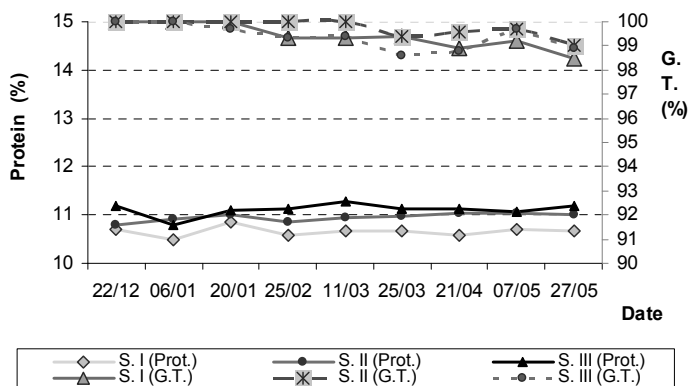


Figure 3 Evolution in time of average protein content (%) and germination percentage (GP %) for three sampling sites (S. I, S. II and S. III) of the bag A.

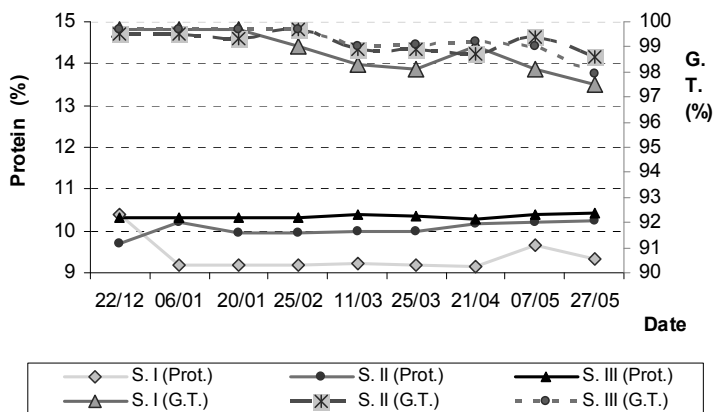


Figure 4 Evolution in time of average protein content (%) and germination percentage (GP (%)) for three sampling sites (S. I, S. II and S. III) of the bag B.

In general, it was observed that values of GP in the upper layer remained above the average value, and more values below average were found in lower layers (Table 1).

Table 1 Germination percentage (GP) values (%) for each sampling level (top, middle and bottom) and average value for each sampling site (S. I, S. II and S. III) for bag A and B at the end of the storage time.

Silobag	Site	Level	GP (%)	Average GP (%)
Bag A	S. I	Top	99,5	98,5
		Middle	97,5	
		Bottom	98,5	
	S. II	Top	99,5	99,0
		Middle	98,5	
		Bottom	99,0	
	S. III	Top	98,5	98,8
		Middle	98,5	
		Bottom	99,5	
Bag B	S. I	Top	97,5	97,4
		Middle	97,7	
		Bottom	97,0	
	S. II	Top	99,5	98,6
		Middle	100,0	
		Bottom	96,2	
	S. III	Top	99,0	97,8
		Middle	96,0	
		Bottom	98,5	

The initial protein content in bag A varied between 11.2 and 10.8%, which fall within the range established by commercialization standard of malting barley (minimum 10%, maximum 12%), and remained stable throughout the period (Fig. 3). In S. I of bag B (Fig. 4) there was a decrease in protein content (from 10.3 to 9.2%) after January 6th. The protein level in S. II of bag B was stable during the 5 months of storage with values close to 10%. The S. III was always with protein values above the limit of commercialization.

Figures 5 and 6 show changes in the average temperatures for each grain layer for bags A and B, respectively. The temperature of the grain in bag A at the beginning of the storage time reached 30°C in all levels of the bag. Over the course of storage time, temperature decreased steadily until the end of February, and remained relatively stable until the end of summer with grain temperature near 20°C.

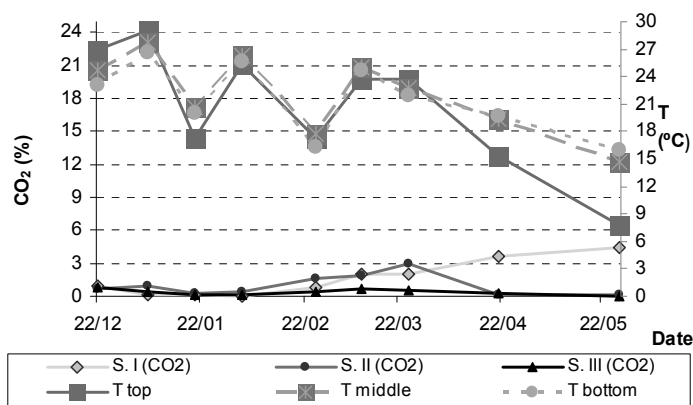


Figure 5 Evolution in time of CO₂ concentration (%) for three sampling sites (S. I, S. II and S. III) and average temperature (°C) for three different levels (top, middle and bottom) of the bag A.

During the fall, temperature of the top layer declined to 9.5°C in late autumn. The middle and lower grain layers presented similar values of grain temperature throughout the summer and early autumn, showing a tendency to decrease towards the late autumn. Temperature of the grain in bag B showed a similar trend as in bag A (Fig. 6).

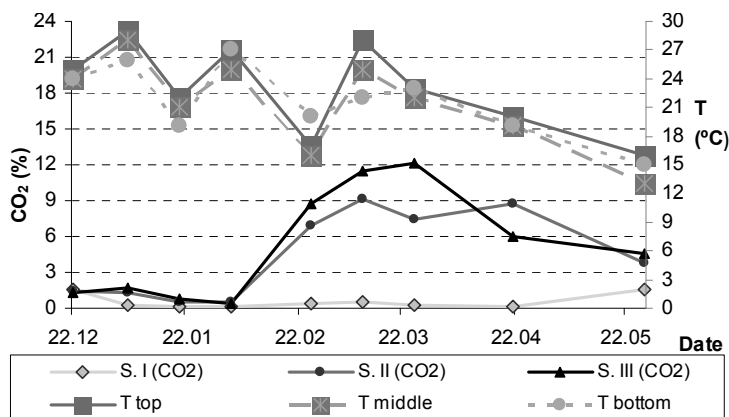


Figure 6 Evolution in time of CO₂ concentration (%) for three sampling sites (S. I, S. II and S. III) and average temperature (°C) for three different levels (top, middle and bottom) of the bag B.

Figure 5 also shows the evolution of CO₂ concentration in Bag A during the 5 months of storage. The area close to the end of this bag (S. III) showed a minor modification of atmosphere (values below 0.5%) throughout the test. In the middle sector of the bag (S. II), the CO₂ concentration started very low, with a peak of 3% in March that slowly decreased towards the end of the storage period. Area S.I also showed low biological activity during the first 3 months of the experiment, having similar values to the rest of the bag. During the last two months of storage a steady increase of CO₂ was observed, peaking at 4.4% on May 22th. In bag B, CO₂ values were below 2% during the first one and half months of storage (Fig. 6). After February 2, the values rose indicating increasing biological activity at the center and end of the bag. Level peaked at 12 and 9% by the end of March for locations S. II and S. III, respectively. The S. I sector of the bag maintained with low and stable CO₂ values throughout the study. During the extraction of grain, isolated areas with damaged grain were observed (between 10- and 15-cm thick) on the low layer of the sectors S. II and S. III of the bag B.

4. Discussion

Even though Figure 1 shows a decreasing trend in m.c. over time, the magnitude of difference between maximum and minimum values of different sampling dates from the same sampling location was only 0.5%. Similar variations have been reported in studies with barley (Ochandio *et al.*, 2009) and other grains (Azcona *et al.*, 2009, Bartosik *et al.*, 2008a). These authors suggested that the low variation in m.c. values could be contributed to the precision of the moisture meter used or to experimental error during sampling. In both bags, m.c. values between layers of the same sampling site were similar (Fig. 1), and there was no increase in the variability of the m.c. over time (Fig. 2), indicating no substantial stratification in moisture level.

Since the silobag is made of a hermetic plastic cover, no moisture variation should be expected during storage, unless rainwater enters the bag through openings. However, Gaston *et al.* (2009) mentioned that a temperature differential between the top layer and the rest of the bag caused migration of moisture from the core of the grain mass to the top layer, and to a lesser extent the bottom layer. Moisture migration can lead to m.c. rise, increasing the risk of grain spoilage (and malting quality deterioration) in localized areas of the silobag. Until now, the magnitude of the moisture stratification process during storage in the silobag was not clear. On the one hand, Darby and Caddick (2007) reported moisture stratification during storage of dry barley ($\leq 11\%$ m.c.) under Australian conditions in non-punctured silobags. This stratification increased m.c. in the peripheral layer up to 13% over winter, but remained dry over summer with temperatures above 30°C, indicating that the grain could be stored in perfect condition for up to 6 months. On the other hand, Ochandio *et al.* (2009) did not find m.c. stratification in 12% m.c. barley silobags, even after 1 year of storage.

Gaston *et al.* (2009) considered that grain m.c., grain temperature, grain temperature fluctuation magnitude and storage time affect the magnitude of m.c. stratification.

As shown in Figures 5 and 6, while grain temperature at the beginning of storage was approximately 30°C (possible higher in the upper layer), this value decreases rapidly. Accordingly, Bartosik, *et al.* (2008a) collected hourly temperature data in different layers of a wheat silobag. Their results indicated that temperature of the grain mass in the bottom and middle layers followed the average monthly temperature (decreasing steadily during the end of summer, autumn and winter), while the upper layer underwent constant changes, following the daily variation of temperature.

The low initial m.c. of grain, the decreasing temperature during storage and the absence of localized m.c. deposition prevented formation of layers of spoiled grain in the periphery of the grain mass. As a result, protein values remained constant in both bags in all sampling points, with the exception of S. I in bag B. The GP was above the industry requirements when m.c. was near 11%. However, where m.c. was higher (11.3 to 11.5%) a tendency for GP to slightly fall below 98% was observed, at the end of the storage time. Contrastingly, Ochandio, *et al.* (2009) did not find changes in the protein levels or GP during storage of 12% m.c. barley.

Low biological activity, as indicated by a minimum atmospheric modification, was observed in bag A and the S. I sector of bag B. Rodriguez *et al.* (2008) pointed out that changes in the atmospheric composition in a silobag containing wheat was mostly explained by grain m.c. The equilibrium relative humidity (r.h.) for barley at about 12% m.c. and 20°C is about 50%, much lower than the r.h. required for storage fungi development (70%). Bartosik *et al.* (2008b) stated that silobags with sectorized spoiled grain had a substantially higher atmospheric modification in compared to silobags or portions of the silobag, with grain in good condition. These authors proposed CO₂ monitoring as an early indicator of a spoiling process of grain in silobags. Based on these observations, it could be hypothesized that the increase in CO₂ concentration observed in sectors S. II and S. III of bag B could be related to an area of spoiled grain produced by rain entering the bag through non visible perforations at the bottom side. Supporting this hypothesis, it localized spoiled grain were observed on the floor of the bag close to sampling locations S. II and S. III. This spoiled grain resulted from gastightness problems with the bag rather than unsafe storage conditions.

Generally, it can be concluded that storing malting barley under typical conditions for Argentina would result in grain temperatures above 35°C in the peripheral layer only 2 to 3 h during hot summer days, decreasing at night to 18-20°C. Temperature of the grain mass will follow the average ambient

temperature through the season, decreasing during fall and winter. The quality deterioration of malting barley increases if the storage m.c. is above 12%. Storing malting barley at high m.c. values can also lead to moisture stratification, with localized moisture deposition in the grain upper layers of grain. This could end with localized spots of spoiling grain, or reduction in the GP. However, storing dry malting barley in silobags (less than 12% m.c.) can be considered safe for a period of up to 5 months.

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