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CARBON DIOXIDE CONCENTRATION IN HERMETIC STORAGE OF SOYBEAN (*GLYCINE MAX*) IN SMALL GLASS JARS

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ABSTRACT

This study aims to establish typical CO_2 concentrations in soybean stored in hermetic systems in the extremes of the common storage conditions (temperatures of 5 and 35°C and moisture content (m.c.) levels of 11, 13 and 17%). The experiment was carried out under laboratory conditions where soybeans samples were conditioned at the three different m.c. and incubated in hermetically sealed glass jars at different temperatures. The CO_2 concentration was measured by gas chromatography. When soybean was stored at 11% of m.c. and 5°C, almost no increase in CO_2 was observed after 1 year (less than 1%), but when it was stored at 35°C the CO_2 increased up to 5-7% after 230 days. At 13% m.c., the CO_2 concentration was also less than 1% after one year when stored at 5°C and was 12% when stored at 35°C for 230 days. For 17% m.c., the CO_2 concentration increased to 5.5-7% after 1 year, while for 35°C, CO_2 concentration was 20-23% after 100 days. Using the results of measured CO_2 concentrations under laboratory conditions, a guideline was developed for evaluating the storage condition of the grain in the silo-bags; however this evaluation has not yet been completed.

Key words: hermetic storage, carbon dioxide, soybean, biological activity, grain respiration.

INTRODUCTION

The silo-bag is a hermetic storage system adopted in many countries for storing dry grains. In Argentina, more than 16 million tonnes of soybean are stored in the silo-bags for a period of 6 months, either at the farm, at the elevator or at the industry level.

A technology was developed for evaluating the storage condition of the grain in the silo-bags based on the measurement of the CO_2 concentration in the bag (Bartosik et al., 2008). The CO_2 was measured in the bag and compared with a reference concentration to detect abnormal biological activity (i.e., grain spoilage, insect activity, etc). Thus, typical CO_2 values of the interstitial air are required as reference levels for this CO_2 monitoring system.

A comprehensive model was developed for simulating storage conditions in silo-bags. The model takes into account the heat and mass transfer according to the grain condition (temperature and m.c.), the ambient temperature and sun radiation. Also, the model predicts the change of O_2 and CO_2 concentrations taking into account grain respiration and permeability of O_2 and CO_2 through the plastic bag (Abalone et al., 2011a; 2011b).

However, in order to further refine the prediction of respiration (O_2 consumption and CO_2 generation) in a hermetic storage condition a suitable correlation that would take into account the effect of the oxygen depleting environment is required. Such a correlation is not available in the literature for soybean. This study aims to establish the typical CO_2 concentrations of soybean (*Glycine max*) stored in hermetic systems at common silo-bag storage conditions (temperatures of 5 and 35°C and moisture content levels of 11, 13 and 17%).

This study is a preliminary part of a more comprehensive study of soybean respiration under hermetic conditions. In the comprehensive study the CO_2 and O_2 concentration were measured for soybean stored at different m.c. and temperatures and the prediction equations were developed. Additionally, biota composition was characterized for different conditions of temperature, m.c. and gas concentration during storage. The germination test, commercial grade and volatiles (AGV and ethanol) were also correlated with storage conditions.

METHODOLOGY

The experiments were carried out at the Balcarce Integrated Unit (UIB in Spanish) of the research station of both the National Institute of Agricultural Technology (INTA) and the Agronomy College of Mar del Plata University, located near Balcarce city, Buenos Aires province, Argentina.

The soybean used in this experiment was collected during the 2011 harvest and consisted of a pool of different varieties grown in southern Argentina. All samples were graded according to the Argentine commercialization standard and also a germination test was performed to ensure that all of the samples were in good condition. Soybean with a condition that would grade them as “out of standard” (i.e., excess of mechanically damaged grains) or with low germination (i.e., due to high mold concentration) could affect the respiration rate and, hence, the experiment.

Soybean samples were conditioned to 11, 13, and 17% m.c. and placed in a chamber at 4°C until the experiment. The conditioning of the samples was done either by rewetting the soybean with distilled water, or drying the samples at laboratory conditions (temperature of 22-25°C and r.h. of 60-65%). The final m.c. was tested with a Dickey John GAC 2100 meter, and the results checked by the oven drying method according to ASAE S 352.2 standard (19 h at 130°C) (ASAE Standard, 2003).

Previous to the experiment, a test was implemented to check the gastightness of two different lids for the glass jars. Empty glass jars of 660 ml capacity were filled with a mix of gasses with 10.5% CO_2 and immediately closed with hermetic lids, one made of metal and other made of rubber. Both types of lids had at the center a perforation sealed with a rubber patch, from which a gas sample could be taken with a needle and syringe.

Gas samples were collected from the jars every 5 days approximately, and CO_2 concentration was measured with gas chromatography (Shimatdzu GC-17A, Kyoto, Japan) equipped with flame ionization red (FID) detector. Fig. 1 shows the results of the test, in which the jars sealed with the metal lid did not result with substantial change in the CO_2 concentration, while the jars sealed with the rubber lids showed a slow decrease in the CO_2 concentration. Thus, the metal lids were selected for a proper sealing of the experiment jars.

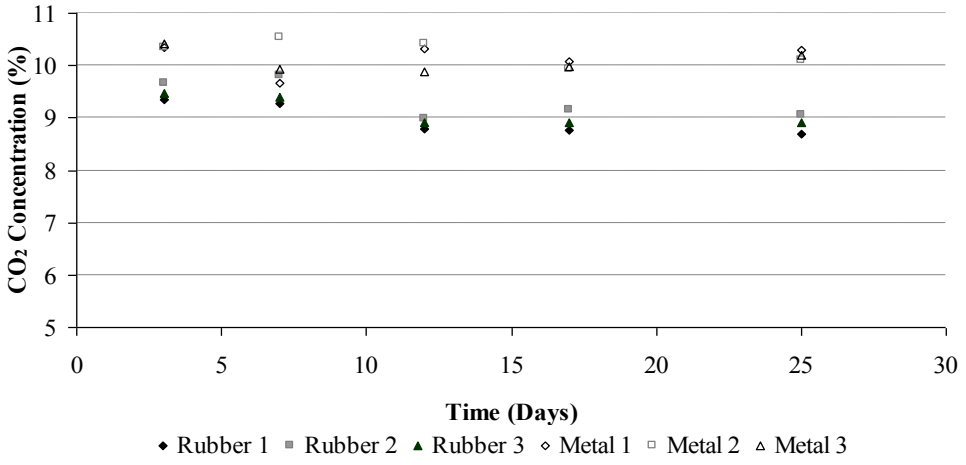

Fig. 1- CO_2 concentration (%) over time for two set of jars with different lids. The initial CO_2 concentration of the gas sample was 10.5%.

The glass jars were filled with 450 g of soybeans each at the three different m.c., occupied more than 90% of the volume of the jar. The empty space (voids) of the soybean filled jars was estimated by measuring the amount of distilled water required to completely fill the jar. The average volume of empty space was of 302.5 ml for 11%, 296.2 ml for 13% and 288.8 ml for 17% m.c. soybean

Two replicates for each m.c. were done at 35°C, while for the samples stored at 5°C three replicates were done. Air interstitial samples were taken with a needle and a 1 ml syringe and analyzed for CO_2 concentration.

RESULTS AND DISCUSSION

Soybean stored a 5°C had, in general, very low respiration. The CO_2 concentration after one year was between 5.5 and 7.5% for 17% m.c., while for 13 and 11% m.c. the CO_2 concentration did not reach 1% (Fig. 2). It could be possible that at 17% m.c. some microorganisms could be active, respiring and generating CO_2, while at 13 and 11% these organisms were not active.

Soybean stored at 35°C had a substantially greater respiration. After one month of storage, the CO_2 concentration in the 17% m.c. soybean reached 15%, tending to stabilize after 100 days to values between 20 and 23% (Fig. 3). The CO_2 concentration of the dryer samples had slower evolutions. At 13% m.c. the concentration reached 12% after 230 days, while for 11% m.c. the concentration reached only 5-7%.

It can be observed that in the experiments at 35°C and 13 and 17% m.c., there is an almost linear increase in the CO_2 concentration up to 10-12%, followed by a slow decay in the increasing rate. In a subsequent experiment (data not shown in this publication) it was observed that when the incubated sample reaches between 10-12% CO_2, the O_2 concentration drops below 1%. This would imply that at that point should be a change in the microbial activity and composition (from aerobic to anaerobic) and, hence, in the respiration rate.

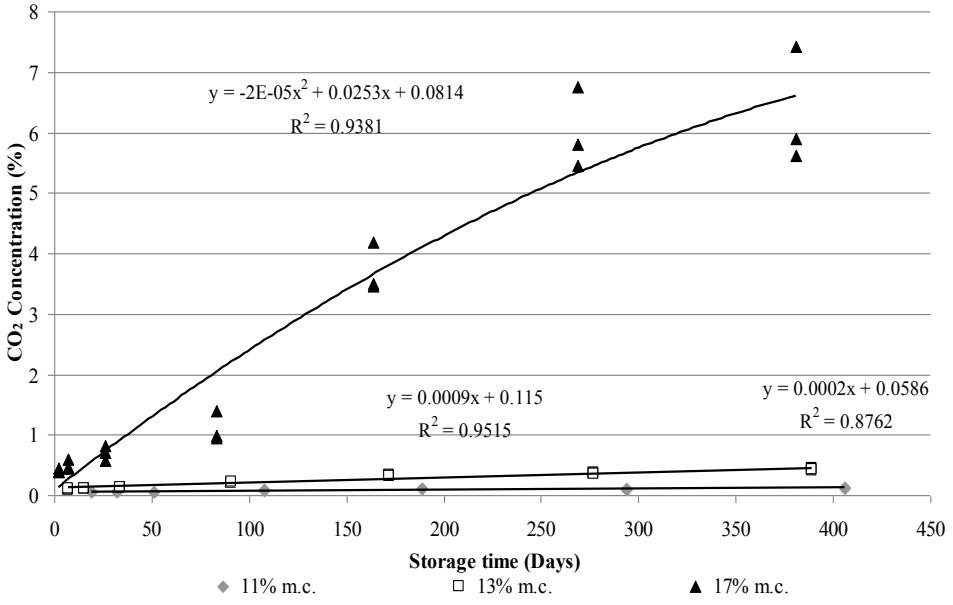

Fig. 2- CO_2 concentration (%) over storage time for soybean at different m.c. stored at 5°C.

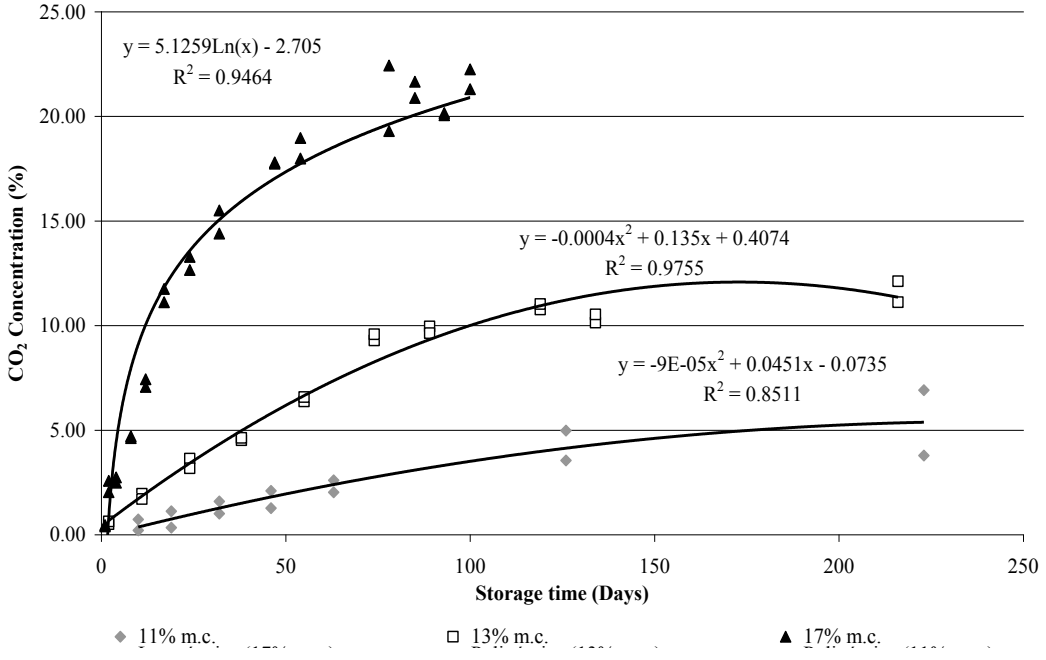

Fig. 3- CO_2 concentration (%) over storage time for soybean at different m.c. stored at 35°C.

Compared with corn, soybean has a lower respiration rate. In a similar study performed with corn at 14, 16, 18, 20, and 22% m.c. and incubated at 30°C, the CO_2 concentration over passed 21% for all the treatments, excepting 14% m.c. Most of the O_2 in the sealed containers with 14, 16, 18, 20 and 22% m.c. was consumed after 600 (25), 120 (5), 48 (2), 24 (1) and 12 (1/2) h (d), respectively. The CO_2 concentration measured after a plateau was reached was from 18% for 14% m.c. to 90% for 22% m.c. The time required to reach the plateau was from 1440 h for 14% m.c. to 480 h for 22% m.c. (Weinberg et al., 2008).

Cardoso et al. (2008) measured the CO_2 concentration in several soybean silobags at m.c. between 10 and 15% and found that, in general, the CO_2 concentration was lower than 1.5% for a storage time from 4 to 9 months in the field. On the other hand, a similar study Rodriguez et al. (2008) found that silobags with wheat from 13 to 14% m.c. had on average 5% of CO_2, showing a substantially higher respiration compared with soybean.

These observations are in agreement with the data presented in this paper. It is recommended in future works to address the evolution of O_2 in the hermetic environment of soybean and the respiration quotient.

CONCLUSIONS

The CO_2 concentration generated by soybean stored in hermetic glass jars was obtained for three different m.c. (11, 13 and 17%) and two different incubating temperatures (5 and 35°C).

Soybean at 11 and 13% m.c. incubated a 5°C almost did not show a CO_2 increase after one year, while soybean at 17% m.c. resulted with an increase of 5.5 to 7.5%.

Higher incubating temperature resulted in higher respiration and, hence, higher CO_2 concentration. Soybean incubated at 35°C during 230 d had a CO_2 concentration of 5-7% for 11% m.c., while when the m.c. was 13% the CO_2 reached 12%. When the m.c. was 17%, the CO_2 reached 20-23% after 100 d.

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