0705

Factors Affecting Carbon Dioxide Concentration in Interstitial Air of Soybean Stored in Hermetic Plastic Bags (Silo-bag)

Leandro Cardoso[1], Ricardo Bartosik*[1], Juan Rodríguez[1] and Darío Ochandio[2]

Abstract: In 2007 about 35 million tonnes of grains were stored in hermetic systems (silo-bags) in Argentina, and about 17 million tonnes of that were soybean. The soybean stored in these silo-bags is mostly used for processing in the local industry (oil and soy – meal), but also for seeds to be used during the next planting season. The goal of this research was to conduct a series of field experiments in order to identify the main factors affecting the CO_2 concentration as an indicator of biological activity and appropriate soybean storability conditions.

The experiments consisted of monitoring the gas composition of the interstitial air, grain moisture content (MC) and temperature of several silo-bags. Additionally, the overall condition of the silo-bags was checked (broken areas, improper sealing, bottom side perforations, etc). On average, biological activity, measured as CO_2 concentration, did not increase substantially when soybean MC increased from 11% to 15.2%. The CO_2 concentration for soybean with 14% MC or lower was below 2%. The average CO_2 concentrations for silo-bags with soybean at 14% to 15.2% MC remained below 2%, however, in some silo-bags the CO_2 concentration increased to 5% at the most. The average temperature of the soybean stored in silo-bags followed the pattern of the average ambient air temperature through the seasons. There was a small increase in the average CO_2 concentration as a function of the grain temperature increase (1.5% points of CO_2 for about 10℃ of temperature increase). When individual silo-bags were analyzed, the CO_2 concentration measured during the warm storage season was up to 3 percentage points higher than when measured during the cold storage season.

Key words: grain quality, biological activity, modified atmospheres

Introduction

During the last 10 years in Argentina soybean production increased 31 million tonnes. As a result, the 2008 soybean harvest was estimated to be 47 million tonnes, representing almost half of the total grain production of the country[1]. On the other hand, the permanent storage capacity did not increase at the same pace as production, so a substantial portion of the harvest, estimated almost 35 million tonnes, was stored in a temporary hermetic storage system, called silo-bags. About half of the grain stored in silo-bags was soybean (17 million tonnes).

Each silo-bag can hold approximately 180 tonnes of soybean and with the available handling equipment is quite simple to load and unload. These plastic bags are 60 m long, 2.74 m diameter and the plastic cover is made of three layers (white outside and black inside) with 235 micrometers of thickness. The silo-bags are waterproof and have a certain degree of gas-tightness (oxygen (O_2) and carbon dioxide (CO_2)). As a result, respiration of the biotic components of the grain mass (fungi, insects and grain) increases CO_2 and reduces O_2 concentrations. When the biological activity is intense, the degree of modification of the typical atmospheric gas composition (21% O_2 and 0.003% CO_2) is greater, which would limit grain respiration and mold[2] and insect development[3,4]. It was also observed that high CO_2 concentration reduced the ability of *Aspergillus flavus* to produce aflatoxin[5].

Bartosik et al.[6] summarized previous experiences of storing grain in silo-bags, where it was demonstrated that the grain temperature in the hermetically sealed plastic bags followed the pattern of the ambient temperature throughout the year, implying that temperature of the grain mass does not reveal biological activity in the grain mass. The average moisture content (MC)

1. *National Institute of Agricultural Technologies (INTA).*
Ruta 226 *km* 73,5, *Balcarce* (7620), *prov. Buenos Aires*, *Argentina*
[*rbartosik@balcarce.inta.gov.ar, Fax*: +54 – 2266 – 439101]
2. *Student Agricultural College of Mar del Plata National University.*
Ruta 226 *km* 73,5, *Balcarce* (7620), *prov. Buenos Aires*, *Argentina*

did not significantly change during any storage experiment for both dry and wet grains. In general, no MC stratification was observed in soybean silo-bags. However, a study of MC change in individual kernels stored in silo-bags showed a slight but significant increase in soybean MC at the top layer (from 11.7 to 12.6 in 60 days)[7]. In general, when grain was stored at the market MC, no significant decrease in the quality parameters was observed during 150 days of storage, and when grain was stored above the market MC, the decrease in some of the quality parameter was observed. However, soybean stored at 12.5% MC resulted in a reduction in the germination test, although other works showed different results[8]. The increase in the CO_2 concentration was higher at the end of the storage time and also was higher in those bags with wetter grain (7.5% of CO_2 for 12.5% MC, and 16.2% of CO_2 for 15.6% MC after 160 days of storage). Based on this observations the authors hypothesized that measurement of gas composition in the interstitial air could be used as an indication of the biological activity of the grain mass in the hermetic storage system, and serve a tool for monitoring grain storability. However, a better understanding of typical CO_2 concentrations for soybean silo-bags is required to use this technology for monitoring grain storability.

Figure 1 shows a diagram of the main factors affecting respiration of the grain and microorganisms in the hermetic storage system and the relationship among them. Based on this model, the CO_2 and O_2 concentration in the silo-bag depends on the balance between respiration (consumption of O_2 and generation of CO_2), the entrance of external O_2 to the system, and the loss of CO_2 to the ambient air. The movement of gases in and out of the silo-bags depends on the gas partial pressure differential and the permeability of the system (through openings in the plastic cover, or through the natural permeability of the plastic material to the gases). Grain type and condition, MC, temperature, storage time, and O_2 and CO_2 concentrations affect the respiration rate. The temperature of the grain depends on the initial grain temperature (this effect is less important as the storage period increases), the effect of the sun radiation, the heat release from the respiration process, and the transfer of heat with the air and soil (grain temperature increases during spring and summer and decreases during fall and winter). The grain MC depends on the initial grain MC, the entrance of moisture from the outside (through openings after a rain event into broken or poorly sealed silo-bags), and the moisture released from the respiration process. Additionally, due to the day and night temperature differential, some moisture condensation can occur in the top grain layers resulting in a localized spot of wetter grain.

Thus, the goal of this research was to study the effect of grain MC and temperature on CO_2 concentration in silo-bags holding soybean.

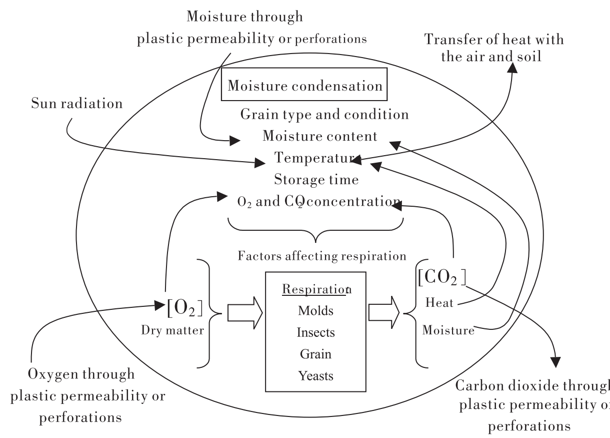

Fig. 1 Diagram of the main factors affecting respiration of grain and microorganisms in the silo-bag, the relationships among them, and the final O_2 and CO_2 concentrations.

Materials and Method

The tests were carried out at grain elevators and on farms in the South East of Buenos Aires province, Argentina during 10 months, from April 2007 to January 2008. Most of the soybean silo-bags were filled in April – May and stored until October or November. However, a small proportion of them were stored for one year period or longer. The silo-bags were sampled every 15 days during the entire storage period.

For each silo-bag two sampling locations were established. The procedure consisted of measuring first the gas concentration (O_2 and CO_2) with a portable gas analyzer (PBI Dan Sensor, CheckPoint, Denmark), perforating the plastic cover with a needle. The gas composition was analyzed for three levels in each sampling location, close to the top of the bag, at the middle and close to the bottom.

After the gas composition was analyzed, a wooden stick with three temperature sensors was inserted in the grain mass (diagonally, from the top and side to the bottom and center of the silo-bag) to measure grain temperature at approximately 0.1, 0.7 and 1.4 m from the surface.

In each sampling location grain was collected from three different levels (surface = 0.10m depth, middle = 0.75 m depth, and interior = 1.6 m depth. Total height of the bag = 1.7 m) using a standard torpedo probe. Material from each one of the three sampling locations was segregated by level (top, middle, and bottom). The grain samples were stored in a hermetic plastic bag and brought to the Grain Postharvest Laboratory of the Balcarce Experimental Station of the National Institute of Agricultural Technologies (INTA). After probing the silo – bags, the openings were sealed with a special tape in order to restore the air-tightness. At the laboratory, grain samples were analyzed for MC (GAC 2100, Dickey – John).

Additional information of the silo-bag was collected, such us filling and sealing quality, history of openings, perforations due to wild animals or bad sealing after sampling, improper preparation of the soil where the silo-bag was placed (when silo-bags were assembled on top of crop residues it resulted in perforations of the bottom), silo-bags assembled in low lands with risk of flooding, and any other relevant information.

Results and Discussion

Figure 2 shows the relationship between grain MC and CO_2 concentration. The data corresponds to silo-bags without visible structural problems, although data from some silo-bags with perforations in the bottom side that were not noticed during sampling might be included.

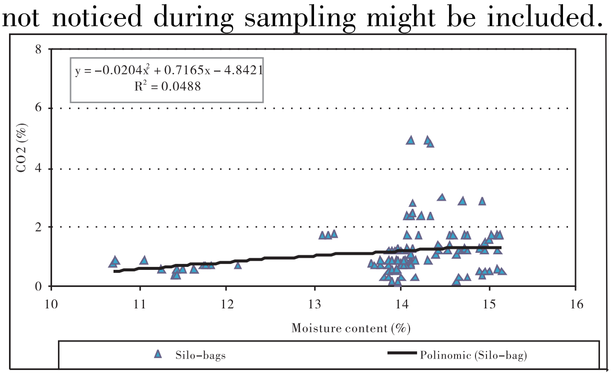

Fig. 2 CO_2 concentration in silo-bags as function of soybean moisture content.

The CO_2 concentration tended to increase very slowly with the increase in grain MC, which most likely was a consequence of the higher biological activity of wet grain (although the R^2 was very low, less than 5%). When the soybean MC was lower than 14% the average CO_2 concentration was below 2% (presumably due to grain respiration). When the soybean MC increased to the point in which molds became active (above 14%) the CO_2 concentration of some silo-bags increased up to 5%. Compared to data from wheat silo-bags[9], the relationship between grain MC and CO_2 concentration was less clear for soybean. Additionally, soybean had less biological activity at the same MC, because for 13% MC the CO_2 concentration was below 2%, while for 13% MC wheat the average CO_2 concentration was about 5%. When the soybean MC increased to 14% – 15%, the maximum CO_2 concentration was about 5% (1.5% average), while in wheat silo-bags for the same MC range the maximum CO_2 concentration was 20% and the average between 7.5% and 12%.

Figure 3 shows the relationship between the average ambient air temperature (data collected from the weather station of Balcarce Experimental Station) and the average soybean temperature in the silo-bags throughout the year.

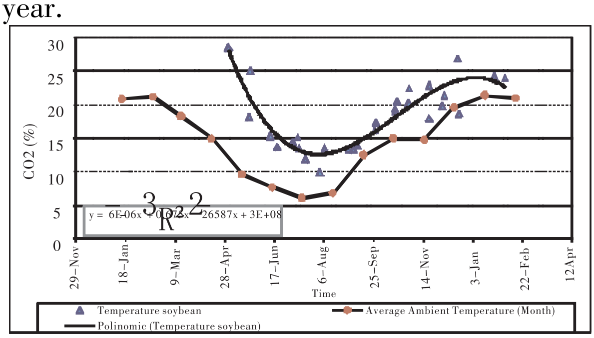

Fig. 3 Average ambient air temperature and average temperature of soybean stored in silo-bags.

This data is in agreement with the data shown by Bartosik et al.[6], where it was demonstrated that the average grain temperature follows the pattern of the average ambient air temperature. From this figure, it can be appreciated that in the early fall (April) the soybean temperature was above 25℃ (most likely soybean was harvested during a warm day). It was hypothesized that grain stored in the silo-bag can easily exchange heat with the air and soil through the large surface area. The surface/volume ratio of a 180 tonnes silo-bag is approximately 1.42, while for a standard metal silo of the same capacity (7 m diameter and 9 m height) the ratio is 44% lower (0.79). As a result, the soybean temperature decreased to about 10 – 15℃ during the winter (June – August) as the average ambient air temperature decreased to 7℃ or lower during the same season. When the average ambient air temperature increased to 15℃ during the early spring and 20℃ later (September – November), the grain temperature increased to 15℃ and to 25℃, respectively.

Figure 4 shows the CO_2 concentration for silo-bags sampled during the winter and spring. Storage temperature affects biological activity, reducing the respiration rate of grain and microorganisms. During the winter time, when the grain temperature was below 15℃, the CO_2 concentration was below 2% for soybean with 13% MC or less, below 3% for soybean between 13 and 14% MC, and below 5% with soybean between 14 and 15.3% MC. When the grain temperature increased during the spring (up to 25℃, Figure 3), the CO_2 concentration increased about 2.5% – 3% points for all MC values (up to 4.5% CO_2 for soybean below 13.5% MC, and up to 8% CO_2 for soybean between 13.5 and 15.2% MC). However, the average CO_2 concentration did not increase substantially with the increase in temperature, as shown in the trend lines.

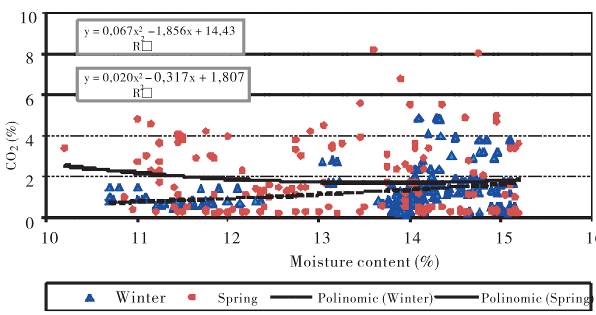

Fig. 4 CO_2 concentration at different grain moisture content for silo-bags sampled during the winter and spring.

Conclusions

On average, the increase of biological activity, measured as CO_2 concentration, did not increase substantially when soybean MC increased from 11 to 15.2%. The CO_2 concentration for soybean with 14% MC or lower was below 2%. The average CO_2 concentrations for silo-bags with soybean at 14 to 15.2% MC remained below 2%; however, in some silo-bags the CO_2 concentration increased to 5%.

The average temperature of the soybean stored in silo-bags followed the pattern of the average ambient air temperature through the seasons. There was a small increase in the average CO_2 concentration as a function of the grain temperature increase (1.5% points of CO_2 for about 10℃ of temperature increase). When individual silo-bags were analyzed, the CO_2 concentration measured during the warm storage season was up to 3 percentage points higher than when measured during the cold storage season.

References

[1] SAGyP. Estimaciones agr colas mensuales, cifras oficiales a 19/05/08: Campa a de cosecha 2007/2008 de soja. Available at: www. sagpya. mecon. gov. ar. Accessed on June 2008

[2] Navarro S and Donahaye J. Innovative environmentally friendly technologies to maintain quality of durable agricultural produce. In: Shimshon B Y ed. Environmentally friendly technologies for agricultural produce quality. Boca Rat n, Florida: CRC Press, 2005: 203 – 260

[3] Banks H J and Annis P C. Comparative advantages of high CO_2 and low O_2 types of controlled atmospheres for grain storage. In: Calderon M and R. Borkai – Golan ed. Food preservation by modified atmospheres. Boca Raton, Florida: CRC Press, 1990: 93 – 122.

[4] Adler C, Corinth H G and Reichmuth C. Modified atmospheres. In Subramanyam Bh and Hagstrum D W ed. Alternative to pesticides in stored – product IPM. Boston: Kluwer Academic Publisher, 2000: 106 – 146

[5] Landers K E, Davis N D and Diener U L. Influence of atmospheric gases on aflatoxin production by Aspergillus flavus in peanuts. Phytopathology, 1986, 57: 1967

[6] Bartosik R, Rodr guez J and Cardoso L. Storage of corn, wheat soybean and sunflower in hermetic plastic bags. Proceedings of the International grain quality and technology congress. Chicago, 2008

[7] Cardoso M, Bartosik R and Rodr guez J. Estudio de la evoluci n de la humedad de los granos individuales en silo – bolsas de ma z y soja. Avances en Ingenier a Rural 2005 – 2007. IX Congreso de Ingenier a Rural y I del MERCOSUR. Rosario: Ed. SIMA, 2007: 410 – 420

[8] EEA INTA Pergamino. Almacenaje de soja en silo – bolsa durante cuatro meses. 2003. Available at: www. elsitioagricola. com. Accessed on June 2008

[9] Rodrl' guez J, Bartosik R, Cardoso M and Crocce D. Factors affecting carbon dioxide concentration of wheat stored in hermetic plastic bags (silo – bag). Proceedings of the 8th International conference on controlled atmosphere and fumigation in stores products. Chengdu, 2008