CO_2 Monitoring of Grain Stored in Silobag Through a Web Application

Ricardo Bartosik*[1], Leandro Cardoso[1], Juan Albino[2], Patrizia Busato[3]
[1]National Institute of Agricultural Technology (INTA), Balcarce Research Station

[2] Silcheck SA, Lincoln, Argentina

[3] Dept. of Agricultural, Forestry and Environmental Economics and Engineering, Torino University
(* Corresponding author: Ruta 226 km 73,5 (7620), Buenos Aires province, Argentina, bartosik.ricardo@inta.gob.ar)

ABSTRACT

Silobags technology is extensively used in many countries for storing dry grains. In the last years, 35 to 40 million tons of grains were stored with this technology in Argentina. Many farming operations have silobags scattered through different regions, separated several kilometers apart that create difficulties for a physical examination of the bags and the quality of the grain.
A technology was developed in which each silobag is tagged with a RFID card. A portable CO_2 meter with a RF reader is used. The meter is first activated with the RFID of the bag, and a number of measurements of CO_2 are made along the 60 m of the bags. A service was implemented to perform the monitoring of the bags every two to four weeks. The information is transferred to a server via GPRS technology and analyzed. The owner of the bags can log-in in a web site and check the storage risk of the bags being monitored with this technology, regardless the location of the bag. In addition to that, if a bag reaches a critical CO_2 value, an alarm is sent to the owner via e-mail, fax, or smt.
This technology is currently used in more than 10000 bags in Argentina and neighbor countries
Keywords: Storage, Grain, Logistic, Silobag, Argentina, Monitoring, CO_2, Storage risk.

1. INTRODUCTION

The silobag is a hermetic type of storage widely adopted in Argentina (35-40 million tons per year). The silobags are made with a plastic bag, with the shape of a tube, of 60 m long and 2.74 m diameter. The plastic cover is made of three layers (white outside and black inside) with 235 micrometers of thickness. Each bag can hold approximately 200 tones of grain and with the available handling equipment is very easy to fill and unload. The bag can be set up in the same production field, or in a field specially dedicated next to the elevator or the processing industry.
INTA has conducted extensive research in the silobag storage technology. The effect of grain MC and storage time on the quality of wheat, corn, sunflower and soybean (Bartosik, 2008a) was extensively analyzed.

Logistic studies were performed showing the advantage and flexibility of the silobags in the harvest operation (Busato et al., 2011). Recently Bartosik (2012) presented a summary of the investigations carried out so far in Argentina regarding to the silobag technology, and Bartosik et al. (2013) presented a new application for estimating the silobag storage cost.

Gas concentration depends on the balance between respiration of the ecosystem, the entrance of external O_2 to the system, and the loss of CO_2 to the ambient air. The transfer of gases depends on the gas partial pressure differential and the effective permeability of the plastic cover (openings and natural permeability of the plastic layer to gases). Grain type and condition, moisture content (MC), temperature, storage time and O_2 and CO_2 concentrations affect the biotic respiration rate (Rodríguez et al., 2008). It was demonstrated that temperature of the grain stored in silo-bags follows the pattern of the average ambient air through the seasons, due to the high surface/volume ratio of the silo-bag, compared to a regular steel silo (this would provide the silo-bag with a high capacity to exchange heat with the air and soil) (Bartosik et al., 2008). Thus, the effect of the biological activity on grain temperature can be obscured by the ambient air temperature effect, which prevents the use of this traditional technology for monitoring silobag storage conditions.

Monitoring the grain storage condition by probing the silo-bags with standard torpedo probes is a process fairly easy to implement. However, each perforation made to the plastic cover disturbs the air-tightness of the system, which limits the number of samples that can be collected from each silo-bag, and the sampling frequency. Additionally, this monitoring procedure is useful to determine the overall quality of the grain stored in the silo-bag (i.e., protein content, falling number, etc), but it is not suitable for detecting early spoilage problems (most of the spoiled grain process occurs in particular locations of the grain mass, typically in the bottom of the silo-bag where the torpedo probe cannot collect the sample). Another disadvantage of this methodology is the amount of labor and time involved.

The silo-bags have a high 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. Thus, the degree of modification of the gas composition in the interstitial air could be related to the biological activity inside the silo-bag, and can be used as a monitoring tool to detect early spoilage problems.

Cardoso et al. (2008) and Rodríguez et al. (2008) studied the main factors affecting CO_2 concentration in wheat and soybean stored in silo-bags. Based on these research studies the typical CO_2 concentration of wheat and soybean stored in silo-bags without conservation problems was established. Bartosik et al. (2008) proposed the used of CO_2 measurement technology for detecting early spoilage problem of grain stored in silobags.

INTA signed an agreement with a private company from Argentina, Silcheck, to develop an on-line monitoring system for silobags based on CO_2 measurement.

The main goal of this work was to implement a monitoring system for silobags using the CO_2 measurement technology and modern data transfer and processing technology.

2. METHODOLOGY

2.1. Silobag tagging

When a silobag is made, a radio frequency identification tag (RFid) is attached to the silobag (Figure 1). Additionally, ten rubber patches are glued along the bag, one every 6 m (10 patches for a standard silobag of 60 m long). Each rubber patch indicates the sampling point where the needle will be inserted to measure the gas composition inside the bag.

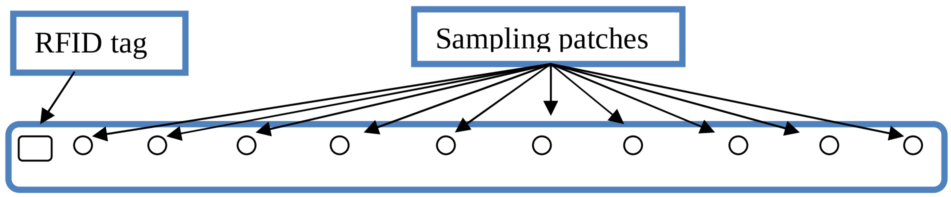

Figure 1. Schematics of the allocation of the RFID tag and the sampling patches in a standard silobag.

2.1. Information

After the RFid tag was attached to the silobag, the tag is activated in the on-line database and the associated information is loaded. The information is divided in location (region, farm, and geographical coordinates), ownership (owner of the grain, phone number, fax number, e-mail) and grain information (bagging date, type of grain, moisture content and quality).

2.1. CO_2 measuring

Silcheck developed its own CO_2 meters, which consist of a CO_2 sensor (infra red technology), a pump for sucking air from the bag to the sensor, a pipe for conducting the air, a needle in the extreme of the pipe. Additionally, the meter has a battery, a data storage system, a GPS, a RFid reader, and a communication module, which is able to transfer data with an GPRS system. The meter is assembled in a heavy duty-waterproof case, which allows for using the meter directly in the field, even under adverse climatic conditions.

The operator activates the meter passing it close to the RFid tag attached to the bag. When the meter reads the tag recognizes the silobag and takes a time stamp and the geographical location. When the meter is activated it allows for 10 consecutive readings. The operator goes to the first sampling point, inserts the needle through the rubber patch and takes the first reading (Figure 2). The pump sucks air from the silobag and the sensor measures the CO_2 concentration. After the first reading was completed, the operator moves to the second sampling point for the second reading and so on until the last sampling point (ten readings in total). Each reading takes about 15 seconds, and monitoring the entire silobag takes less than 5 minutes.

Figure 2. Meter monitoring the CO_2 concentration of a silobag, with the detail of the rubber patch used for inserting the needle.

In addition, when the operator moves from one sampling station to the next, can add additional information into the silobag database. Two main aspects are considered: silobag openings (perforations, bad seals, etc) and soil flooding evidence. To enter this information the operator has two buttons in the meter, and the information is attached to the last sampling point. This information is useful for analyzing CO_2 changes during storage.

Once the operator finished monitoring one silobag, moves to the next one, activates the meter with the RFid tag and starts collecting data of the new bag.

The system indicates to the operator the frequency of monitoring (after how many days has to come back to the same bag), which is shorter in summer time and longer in winter time due to the effect of the ambient temperature. If the system does not register new measurements in a particular silobag, it sends an automatic warning to the owner of the bag indicating that the bag should be monitored.

2.1. Data processing

After the data was collected (from one or many silobags) the operator can transfer them to a centralized server, either via GPRS technology or by downloading the data from the meter to a computer through a USB port, and from the computer, with a custom made software, uploading the information to the server.

Once the information arrives to the server, the CO_2 concentration values are compared with a referential chart (Figure 3). The chart was constructed with previous research data and relates the storage condition of the grain with the CO_2 concentration. In addition to the grain moisture content (data provided by the owner of the bag, or determined from a sample collected from the bag right after bagging) and the CO_2 concentration determined with the CO_2 meter, the system takes into account the location of the bag (related to the average ambient temperature), the storage time, the previous CO_2 value and the ruptures of the bag to classify the storage condition in safe, ambiguous or risky. Each section of the bag is classified in term of the storage risk, and the entire bag also receives a classification.

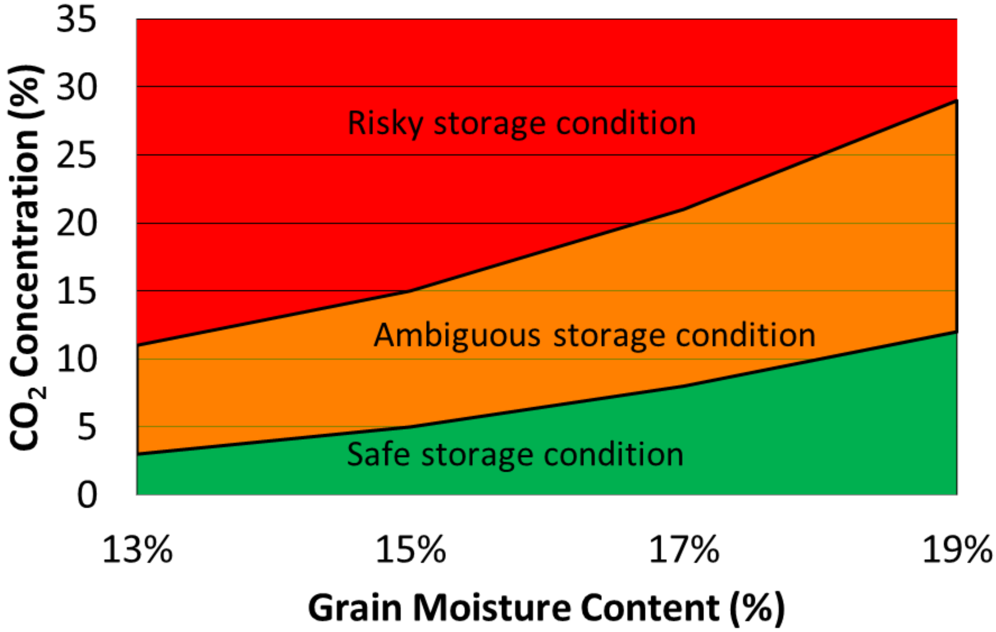

Figure 3. Chart showing the regions considered as risky, ambiguous and safe based on the grain moisture content and the CO_2 measurement for a generic grain.

2.1. Reports and warnings

There are several ways in which the system interacts with the users regarding to the report of the information. The most complete one is through the web, in which the user logs in into the Silcheck web page and sees the main screen, with different levels of information (Figure 4).

On the left side the list of the silobags being monitored is shown in a color scale. This view allows the user to quickly identify which bags are in safe storage conditions and which bags are in risky storage conditions. By selecting an individual bag from the previous list, more detailed information of the selected bag is shown. In the upper-left frame the information of the client (name, address, contacts, etc) is shown. Additionally, information of the bag is also provided, which includes type of grain, moisture content and other quality parameters, bagging date, location of the bag, etc. In the upper right side a map shows the geographical location of the bag based on the information provided by the GPS unit.

In the lower side of the screen there is detailed information of each one of the ten environments in which the silobag is divided for taking gas samples. Each section of the bag represents 6 m in the real bag, and the color scale indicates the storage risk in each section.

Additionally, the user of the system can receive the information regarding the status of the monitored silobags via e-mail, cell phone message or fax in regular basis (i.e., once a month). However, when a particular silobag is classified by the system as risky, the owner of the bag receives an immediate warning via e-mail or cell phone message.

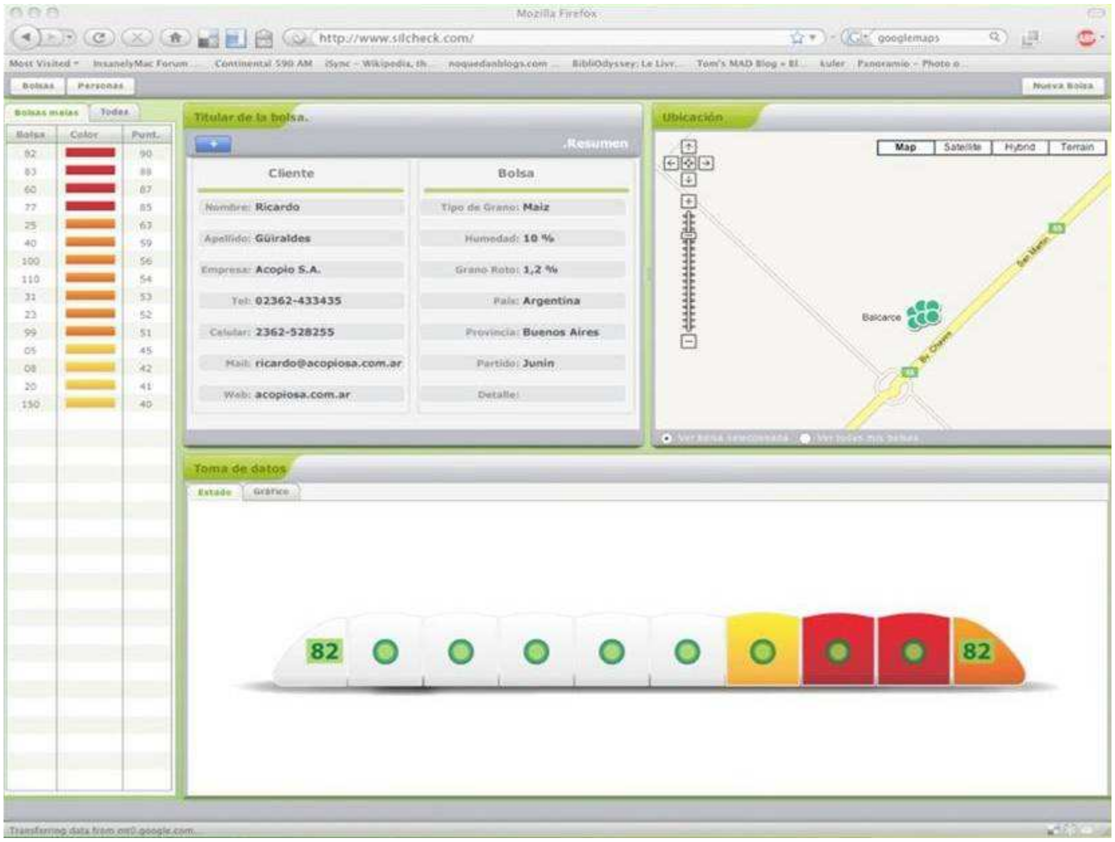

Figure 4. Screen capture of the main menu of the web monitoring system.

3. RESULTS AND DISCUSSION

Silcheck made an agreement with INTA for developing the silobag monitoring system based on the measurement of the CO_2 concentration in year 2007. After 3 years of development, the system was commercialized in Argentina, as a service. Today the service is also offered in five countries. The number of silobags monitored with the CO_2 technology increased every year, with important benefits for those farmers and companies which applied this technology.

The main consequence of CO_2 monitoring is that the managers of the silobags can have a real dimension of the storage risk of the bags, which allows for properly planning the sales, unloading first those bags that are under risky conditions and keeping for a delayed sale the bags that are in safe storage condition. Furthermore, the CO_2 monitoring detect problem such as storing wet grain, entrance of water due to improper sealing, ruptures of the bag due to poor soil preparation and perforations due to animal damage among other problems. Before the implementation of the CO_2 monitoring these problems were not noticed, unless the consequences on quality were important enough to affect the selling price. The CO_2 monitoring allow for a diagnosis of the overall silobag operation and improvements can be made year to year in order to reduce the storage risk and maximize the economic benefit of the silobag operation. Figure 5 shows the results of the implementation of the CO_2 monitoring in approximately 5000 silobags in Argentina. In the first year of monitoring (2010/2011), 46% of the bags were classified as safe, 42% as ambiguous and 12% as risky. The silobag managers of the different companies modified their “modus operandi” regarding the bags (soil preparation, sealing, maximum storage moisture content, storage time, unloading order, etc) and substantially improved the overall storage conditions of the silobag in the second year, in which 83% of the bags were classified as safe. Currently, this technology is used in more than 10000 bags in Argentina and neighbor countries.

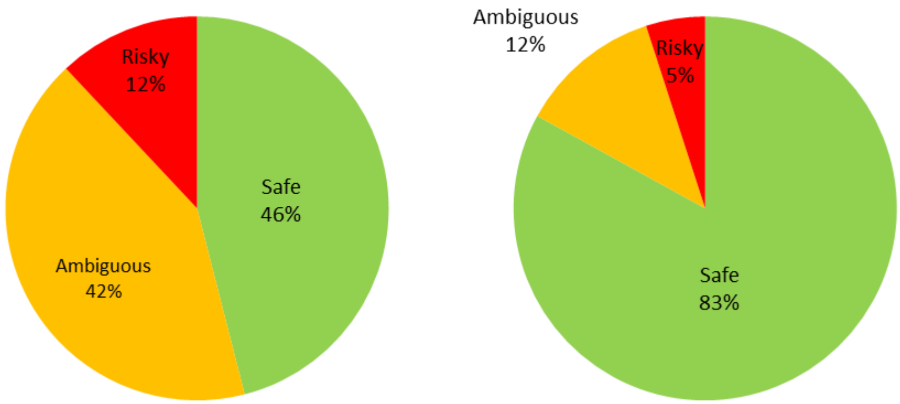

Figure 5. Classification of silobags according the storage risk based on the Silcheck monitoring system for years 2010/2011 (left) and 2011/212 (right) on a basis of 5000 silobags.

4. CONCLUSIONS

A novel monitoring system for silobags based on CO_2 measurement was developed by INTA.

This technology was implemented by a private company (Silcheck) as a service. The CO_2 meter is integrated with RFid tag, GPS and data transfer system. A web application was developed for sending reports to the silobag owners regarding the storage risk. In addition to that, if a bag reaches a critical CO_2 value, an alarm is sent to the owner via e-mail, fax, or smt.

The implementation of the silobag monitoring system helped to reduce the storage risk from one year to other. More than 10000 silobags are being monitored under this system.

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