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Environmental control in rural underground storage structures

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RESUME: Le stockage souterrain des céréales est une technique utilisée en milieu rural dans differentes régions du monde pour les avantages qu'elle présente : coût réduit, reduction des effets de variation de température de l'air, et création d'un environnement désoxygené, dans la masse de grain émmagasinée. De plus, le revêtement interne de tels entrepots joue un rôle important dans la réduction des risques de contamination du grain stocke par les eaux souterraines.

Cette communication présente les résultats obtenus à l'issue d'experiences menées sur le stockage du blé pendant six mois dans les entrepôts souterrains. L'étude a consiste à suivre l'évolution de la temperature, du grain emmagasiné, du CO_2 et de l'humidité relative d'unités de stockage à localiser les zônes de pertes et à évaluer les dégats occasionnés par ce type de stockage en comparant l'effet de deux types de revêtements interne des entrepôts: la paille et le plastique.

ABSTRACT: Underground grain storage is a technique which is used in rural areas in several parts of the world because of the following advantages : its cost is lower compared to other techniques of storage; the effects of the variation of the temperature of the air are reduced and the pits create an environment for the grain masse where oxygen is reduced. Moreover, the interior lining of the walls of these units play an important role in the reduction of the risks of the stored grain contamination by the underground water.

This paper presents the results of an experiment conducted on wheat which has been stored during six months in underground pits. The study consists in monitoring the temperature change of the stored grain, CO_2 and relative humidity variations of the pit environment. Finally loss areas are located and the damage due to this kind of storage is estimated by comparing the effect of two types of wall pits lining : straw and plastic.

ZUSAMMENFASSUNG

Die Unterbodenlagernug der getreide ist eine Technik, die in vesschiedenen Landern der welt am meisten benutzt wird.
Die Vorteile dieser Technik sind :
- Geringe Kosten
- Geringe temperaturschwankungen
- Anschaffung anarober umgebung im Getreidelager.

Der Innenbelag dieser Lager spielt eine grosse Rolle bezuglich der Reduzierung der Verseuchung der getreide mit dem Grundwasser.

Dieser Kurzvortrag umfasst die Ergebnisse der Versuche uber Getreidelagerung wahrend 6 Monaten in Unterbodenlagern.
Diese Studie befasst sich :
1) mit dem Verhalten von der Gelagerten Getreide.
2) mit der entwicklung von CO_2 und Feuchtigkeitngehalt der Lager.
3) Bestimmen der Verlustszonen
4) Bewerten der Verluste dieser

Lagerungsart bezuglich dern Sttoh-bzw. Plastik-Innenbelag dieser Lager.

1. INTRODUCTION

On farm Underground grain storage is widely used in many parts of the world, particularly in countries with developing agriculture where this technique represents a substantial proportion of rural grain storage facilities. The use of Underground space to store grain is a technique which has been known for centuries because it offers several advantages namely low cost, insect attack reduction, O_2 level reduction. Interior lining of these Underground facilities usually consists of straw lining (straw is used for its thermal insulation properties) or independant plastic pieces nailed to each other. In both situations, Underground water manages to reach the stored grain and contaminates it, thus increasing the loss rate. In order to help reduce or even eliminate the rate of seepage, an investigation on the use of plastic bags as lining for the walls of the underground grain storage has been carried out over a period of 15 months.

2. MATERIALS AND METHODS

The experiment site for this investigation is located on farm in order to allow for a demonstration of the technique to farmers and for its extension. The site altitude is 257 m and the water table level is at 60 m below ground. The soil and subsoil profil is shown in figure 1.

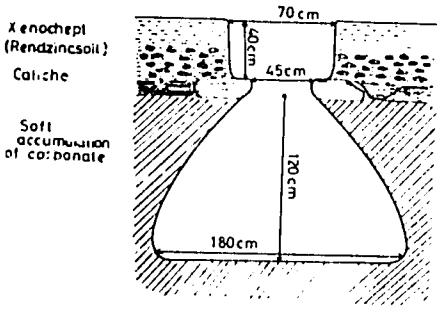

Fig.1 : Vertical section of pit

On October 1987, sixteen experimental underground pits with 1.3 metric ton capacity each were dug on a rectangular area (15 x 20 m). The interior of each pit is conical, the bottom width being larger than the top (figure 2)

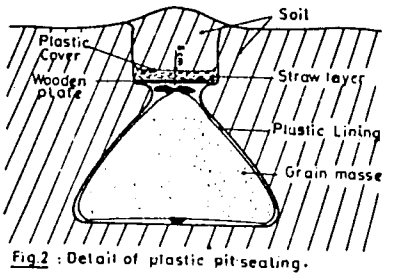

Fig.2 : Detail of plastic pit sealing.

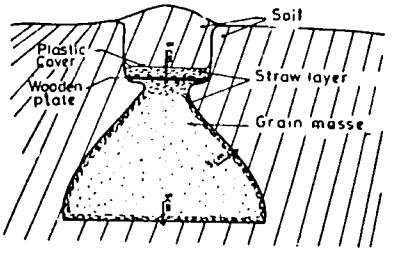

Fig.3 : Detail of straw pit sealing.

Eight pits were plastic lined and eight others were straw lined (fig. 2&3). The sixteen pits were equiped with data measurement instruments, filled with durum wheat and covered with earth in order to provide a hermetic sealing. The plastic used is polyethylene with the characteristics shown in table 1.

Table 1. Polyethylene characteristic

	Thickness (mm)	Permeability to water	Permeability to O_2
Polyéthylene	0.18	Null	68cm³/cm²/24h at 25°C

The experiment consisted in conducting continuous control of environment conditions within the grain mass and the surrounding soil by a remote measurement of temperature and relative humidity, and direct measurement of CO_2. Every 3 months, four pits are opened and grain samples are taken and analyzed to evaluate damage. (Fig.4)

A multidisciplinary team of scientists contribute in their respective laboratories to conduct analysis on the following aspects :

- unit weight and moisture content of grain
- dry weight loss
- insect damage
- fungi damage, and microbology analysis

2

- chemistry and biochimistry analysis
- rheological analysis
- germination and vigor test

Temperature and relative humidity were continuously monitored using battery operated data loggers installed on the experiment site. These are equipped with 24KB of RAM able to store 12,000 measurements. Communication with the data logger and data recovery are made by means of portable microcomputers . Relative humidity is measured in 2 pits with two different linings. CO_2 concentration inside the storage pits is measured with a pump that draws the air and sends into color detecting tubes.
The filling of experimental pits was achieved on December 30th 1987. In this paper the first 6 months of this experiment are covered. i.e. 4 pits were opened 3 months after the initial filling and 4 others were opened 6 months after they had been filled.

3. RESULTS AND DISCUSSION

3.1. Environment conditions control

a. Climatic conditions

Figures 5 and 6 indicate the climatic conditions that prevailed over the 6 months considered. The first quarter was characterised by a relatively important rainfall, compared to the second quarter.

b. Temperature

In vertical direction temperature gradient in both grain mass and soil are shown in figures 7 and 8.

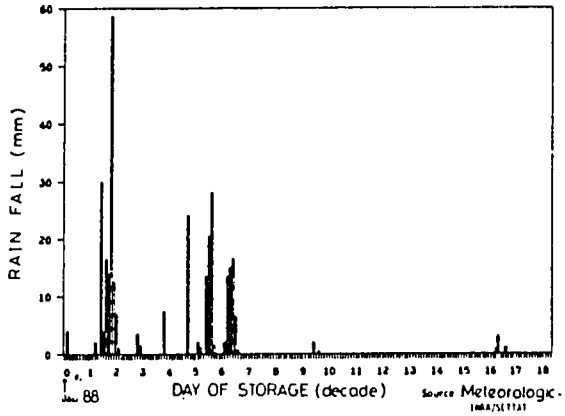

Fig.5 : RAIN FALL IN SITE OF EXPERIMENT.

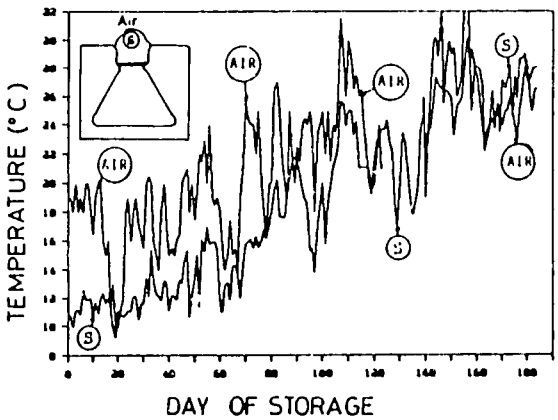

Fig 6 : AIR TEMPERATURE

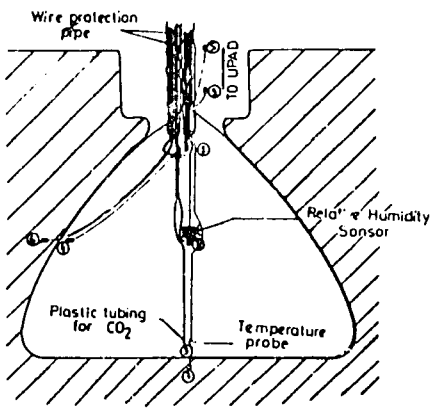

Fig 4 : Diagramme of instrumented pit .

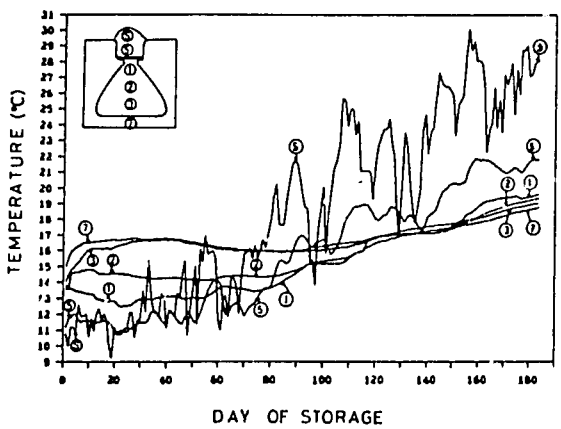

Fig 7 PLASTIC LINED PIT.
Vertical temperature gradient.

3

It indicates that :

- Temperature flucturations of soil surfa- (curve S) decrease with depth (curves 5 and 7): The temperature of the pit bottom (curve 7) has remained close to the value of 17°C. Soil, thus plays the role of a thermal insulator.

For the plastic lined pits; the curves indicating the variations of grain temperature (curves 1,2 and 3) are comprised between the two curves 5 and 7 of the soil. This observation applies for the 6 months storage period. No excessive temperature was observed. The grain temperature was thus affected by the soil environment temperature because of heat transfer by conduction. Consequently the grain temperature didn't exceed 20°C.

As to straw lined pits; a noteworthy increase in grain temperature was noticed especially in fig. (1) and (2)/ The metabolic activity of the ecosystem. formed by the grain and the microorganisms was important. We think that the proliferation of the soil moisture towards the grain through the straw layer and the thermal isolation of this latter have jointly contributed to the wheat temperature increase.

c. Relative Humidity

The relative humidity sensor which was set in the plastic lined pit stopped functionning 2 days after the grain had been stored. Fig.9 shows the variation of the relative moisture in the center of a straw lined pit. The perturbations which occured during the 2 first months were mainly due to direct current cut between the data glogger and the sensitiveness of the sensor to the proliferation of water drops along the protecting pipe as shown in (Fig.3). Fig.8 shows that the relative moisture has become stable by the end the storage period (around 71 %).

Besides, at the time of the opening relative humidity in the center of the opened pits; has been measured by an apparatus called hygrometre.

The results have been shown in table 2.

Table 2 : Relative moisture in the center of the pits measured by a hygrometre

Storage period	Plastic lined pits	Straw lined pits
3 months	67.5 %	80 %
Six months	65 %	75 %

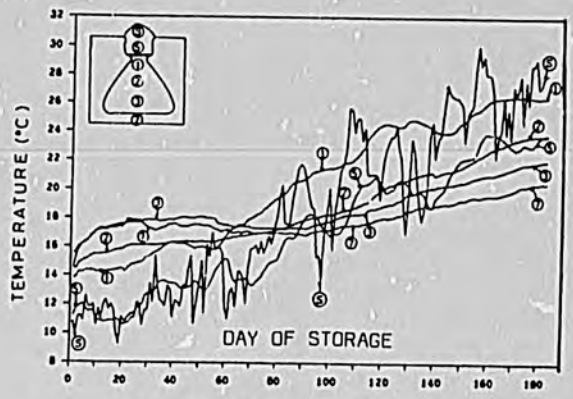

Fig 8 : STRAW LINED PIT
Vertical temperature gradient

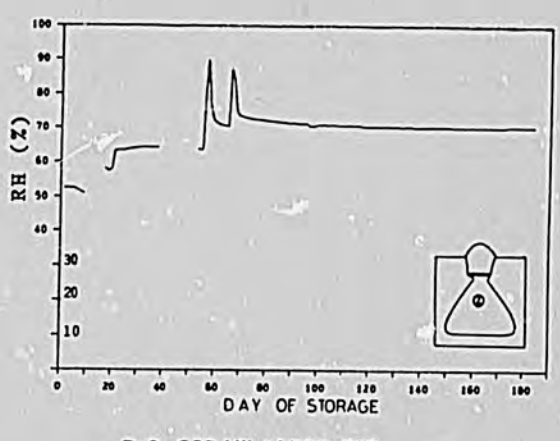

Fig9 : STRAW LINED PIT.
Relative humidity at the center of pit

This data show that the level of the relative humidity reached in the straw lined pits could increase the different chemical alteration of the grain and will alow a rapid increase of microorganisms. Nevertheless, the level of the relative humidity reached in the plastic lined pits could hinder the two previous phenomena.

d. CO_2 concentration

Figures 10 & 11 show that the concentration in terms of CO_2 are relatively higher in straw lined pits than in plastic lined ones. The grain and microorganisms respiration was thus reduced in the latters.Hermetic environment and the low oxygen permeability of the plastic bags were such that the CO_2 content increased at the expense of O_2 content.

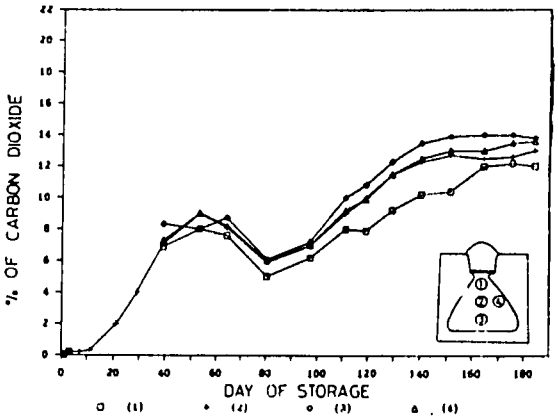

Fig 10 PLASTIC LINED PIT
Variation of CO_2 levels

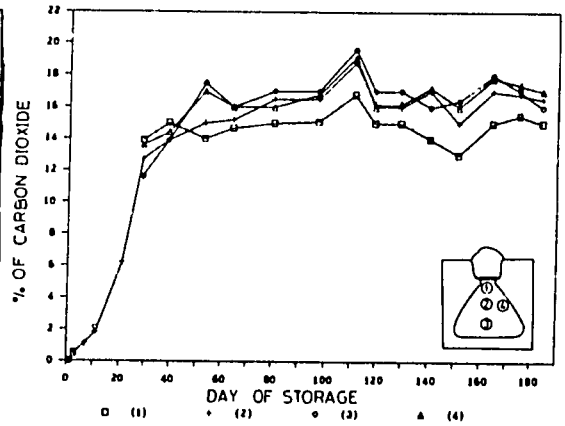

Fig 11 : STRAW LINED PIT.
Variation of CO_2 levels

..2. Sample Analysis

During the time of the 2 openings, wheat samples were taken at different levels of the pits. Wheat taken from plastic lined pits has kept its odor and its colour while the straw linned pits wheat of the top ; the bottom and the pit walls has become dull with a strong rotten smelling.
The comparison of the analysis results of wheat samples of the two types of lining is reported on table 3.
As a result, losses in terms of quantity as well as quality were reduced in plastic lined pits. Thus, the degree of humidity, unit weight, the damage percentage and the rate of germination have been maintained to levels close to initial values.

Insects haven't been developed while fungi and acarid have rapidly developed during the first term. We think that the decrease in O_2 concentration along with an increase in CO_2 concentration caused these variations.
As far as straw lined pits are concerned, apart from insects which did not develop, all the other parameters have significantly deteriorated. The following conclusions could be drawn : moisture content increased and as a result dry weight decreased ; fungi and acarid infestation occured; germination rate was reduced as well as seeds vigor.

TABLE 3 - Wheat samples analysis results

Source : GERS/IAV

Analysis	Initial (1)	3 months storage period		6 months storage period	
		*PLP(2)	*SLP(2)	PLP(2)	SLP (2)
Moisture content (%)	11.76	12.05	18.26	12.03	17.25
Unit weight (g/l)	775.5	770.5	683.3	769.5	692.6
Damaged grain (%)	7.78	7.13	20.61	8.14	22.17
Insect infestation	+	+	+	+	+
Acarid infestation	0	++	++++	+	+
% of infested grain by fungus (%)	100	90	96	85	86
Number of mold spores per /gr.	940	21500	423000	16	321000
Germination rate (%)	96	92	53	91	46
Vigor test of 18 kernel dry weight of plants in g	543	425	80	160	75
Free fat acid content (mg KOH/100 g of flour)	n.d	43	72	28	35
Fermentation activity (Hagberg index drop in S)	833	859	556	579	699
Rate of loss in dry weight in %	-	0.97	18.05	1.07	16.15

* SLP : straw lined pits
PLP : plastic lined pits
n.d : not determined
(1) : average of 18 samples
(2) : average of 10 samples

0 : non infested
\+ : very low infestation
++ : low infestation
+++ : medium infestation
++++ : very infested

-5

4. CONCLUSION

Underground grain storage is a practice which is well adapted to rural areas because of its relatively lowcost, the practical aspect of its management and its longevity due to its stable structure.

Thermal insulation which the soil offers as well as thermal environment which could be insured by using plastic bags contribute, in a significant way to reduce grain loss due to storage. Other factors could be in favor of this storage technique, normely, storage capacity and pit depth. The deeper the pit, the lower and more stable the temperature of the grain mass is.

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