EFFECT OF UNDERGROUND STORAGE ON SOME CHEMICAL, AND RHEOLOGICAL PROPERTIES OF WHEAT

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ملخص

يقوم عدد كبير من فلاحي المغرب بخزن المحاصيل السنوية من الحبوب في مخازن تحت الأرض، يسمونها «المطامير»، وتجدر الإشارة هنا إلى أن القمح المخزون بهذه الطريقة يتعرض لآفات عديدة يمكنها أن تؤثر على جودته.

هذا وقد ساعدت هذه الدراسة على متابعة التغيرات، وتقييم الأهمية وذلك بتخزين عشرين طناً من القمح الصلب المغربي، نوع وادرْناتي 2909، لمدة ستة عشر شهراً ونصف في مخازن تحت الأرض «المطامير»، غطيت جدرانها الداخلية بالتبن أو البلاستيك، بحيث اتضح لنا جليا طوال هذه المرحلة مدى تطور الجودة التي تم تمييزها حينما أخذت عينات من أربع مواضع مختلفة من كل مطمورة وتحليلها بطرق كيماوية وفيزوكيمائية ومايكروبية ريولوجية.

ولدى اختبار المميزات الريولوجية بالمايكسوجراف عرفت هذه الأخيرة إلى جانب درجة تحليل الدهنيات تغييراً كبيراً جاء نتيجة لمدة الخزنة الأنفة الذكر.

ومن التأثيرات الرئيسية للتخزين، ازدياد مدة الخلط المناسب كما أن مستويات كل هذه التغييرات جد مهمة في المطامير التبينية بالمقارنة مع الأخرى البلاستيكية.

وتم أيضا تسجيل زيادة مهمة في عدد تجمعات الفطريات المجهرية في المخازن المفروشة بالتبن، في حين لم يحدث إلا تغييراً طفيفاً نسبيا في عدد هذه الكائنات لدى المخازن المغطاة داخليا بالبلاستيك. كما تم ضبط وجود عوامل ترابط مهمة بين الصفات الريولوجية من جهة والمعايير الكيماوية، الفيزيوكيمياوية من جهة ثانية أخرى، وذلك في المطامير التبينية بالخصوص. وعلى العموم يمكن القول على أن تغطية المطامير بالبلاستيك ساعد بكثير في الحفاظ على جودة القمح المخزون.

كلمات جوهرية : القمح، الخزن الجودة.

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RESUME

Le stockage souterrain des grains de blé est pratiqué par beaucoup d'agriculteurs au Maroc. La qualité du blé peut changer considérablement au cours du stockage. Cette étude a été menée pour suivre ces changements et en évaluer l'importance. Vingt tonnes de blé dur (variété Oued Zenati : 2909) ont été stockées pour une durée de seize mois et demi dans des fosses souterraines (<Matmoras>) revêtues de paille ou de plastique. Au cours de cette période, l'évolution de la qualité a été appréciée par des tests chimiques, physico-chimiques, microbiologiques, et rhéologiques .

Des échantillons de blé ont été prélevés de quatre positions différentes, après 3, 6, 9, et 16,5 mois de stockage. Les propriétés rhéologiques (test au Mixographe) et le degré d'hydrolyse des lipides ont été affectés par la durée de stockage. Une augmentation du temps de développement de la pâte et un accroissement de l'acidité grasse ont été enregistrés. L'humidité et l'activité de l'eau ont également sensiblement augmenté. Le nombre de colonies de moisissures dans les fosses revêtues de paille a substantiellement augmenté. L'intensité des variations de tous ces paramètres est plus importante dans les fosses revêtues de paille. Les critères chimiques et rhéologiques ont été mieux corrélés entre eux dans les fosses à revêtement en paille. En général, le blé a relativement mieux conservé sa qualité dans les <Matmoras> revêtues de plastique que dans celles revêtues en paille.

MOTS CLÉS : Blé ; Stockage ; Qualité.

ABSTRACT

Underground storage of wheat grains is commonly practiced by farmers in Morocco. Grain quality may be seriously altered over time of storage. The objective of this study was to monitor quality changes of wheat stored in underground pits. Durumwheat (Triticum desf.) cv. Oued Zenati was stored for up to 16.5 months in underground pits (Matmoras) with either straw or plastic as internal liners, and its quality was monitored using chemical, physico-chemical, microbial, and rheological tests. Grain was sampled in the pit at four different positions in the pit after 3, 6, 9, and 16.5 months of storage. Mixograph properties and the degree of fat hydrolysis were affected by storage duration. The main storage effects included an increase in dough mixing time and an increase in fat acidity, moisture content, and water activity. the number of mold colonies increased substancially in pits lined with straw, whereas in plastic-lined pits the mold count did not vary significantly. The magnitude of these changes was higher in straw-lined pits. Correlation coefficients showed that the chemical and rheological changes were better related in straw-lined pits compared to those obtained from pits lined with plastic . Generally, the pits lined with plastic maintained much of the initial properties of wheat, compared to those lined with straw.

KEY WORDS : Wheat; Storage; Quality.

INTRODUCTION

Postharvest losses are quite important in Morocco. The nature and importance of grain deterioration is closely related to the kinds of storage facilities used. In Morocco, underground storage. still is one of the major methods used by farmers to store harvested wheat . The storage structure used is called : < MATMORA >. It is a cone-shaped pit with the diameter increasing from the top to the bottom. The interior walls are always covered with a thick lining made of clay and straw. The storage capacity varies generally from one to five metric tons. Despite some handling problems, the storage of wheat in such airtight conditions is supposed to protect the grain from important temperature fluctuations, and limit insects and mold proliferation via the creation of an environment whose oxygen content decreases with storage duration (Bartali et Debbarh, 1990) . The changes that occur in chemical, physico-chemical, and rheological properties of wheat during storage depend upon several factors such as temperature, humidity and storage duration. The edibility (or) wholesomeness of stored wheat is very sensitive to moisture content variation (Fellers & Bean, 1977). In fact, molds start to grow significantly when moisture content exceeds 13 to 14% (Sauer, 1988) . When moisture content is above 16 %, it leads to extensive deterioration of bread-making quality of wheat stored in airtight conditions (Hyde & Burrel, 1982 ; Shearer & Warwick, 1983) . The major chemical change that occurs during storage of flour or wheat grains in either open-air or airtight conditions is lipid deterioration via enzymatic hydrolysis reactions that generate free fatty acids (Daftary & Pomeranz, 1965 ; Daftary et al., 1970 a ; Girish et al., 1972 ; Warwick et al., 1979 ; Gallaind, 1983 ; Shearer & Warwick, 1983 ; Leelavathi et al., 1984). This hydrolysis is catalyzed by both seed and microbial lipases (Daftary & Pomeranz, 1965 ; Galliand, 1986) . Many authors reported that lipid hydrolysis paralleled wheat quality deterioration. Impaired rheological properties have been observed when wheat or flour stored at high moisture contents and in low or normal oxygen concentration, is invaded by molds . Mixing time, resistance to extension, and dough stability increased, whereas dough extensibility, flour water absorption, and loaf volume decreased. indicating that gluten visco-elastic properties are seriously altered (Pomeranz et al., 1956 ; Pomeranz et al., 1968 ; Daftary et al., 1970b ; Leelavathi et al., 1984).

Concerning the gassing power, Pomeranz et al. (1968) reported that it was not significantly affected by storage duration . This was also noted by Pixton et al. (1975), who reported that the activity of alpha-amylase reached levels below the minimum required for normal fermentation, only after eight years of storage.

The purpose of this study is to look at the quality changes of wheat stored in underground pits, by analysing some chemical (moisture content, and free fatty acids), physico-chemical (water activity), microbiological (mold count), and rheological (Mixograph : Mixing Time, Peak Height, and Weakening Angle) parameters. Alpha-amylase activity is also assessed using the Hagberg test. The pits were lined with either straw or plastic so as to look for the benefits of having one or the other lining material in terms of preserving wheat from adverse storage effects.

MATERIALS and METHODS

Wheat sampling and storage conditions

20 tons of sound durun wheat of the Oued Zenati variety (2909) crop year 1987, were stored in sixteen identical underground pits ("matmoras") for 16.5 months . The pits were lined with straw or plastic material (polyethylene : 0.18mm thick, water permeability : insignificant, and oxygen permeability : 68 cc. / cm 2 /24 hours) . A typical scheme of an experimental pit is reported in figure1. After a given storage period, two pits lined with straw and two others with plastic are opened and sampled at the 4 positions indicated in fig. 1 ; Thus, the numbers in table I for instance, are, averages of 16 values : 2 pits x 4 positions x 2 replicates . At zero time, 15 determinations were made.

Moisture content

Moisture content was determined by oven drying according to method 44-15a of the American Association of Cereal Chemists (A.A.C.C. Methods, 1984)

Water activity (AW)

The water activity was determined using a DT Kaynont hygroscope (Kaymont Instrument Huntington Station, NY) . The DT instrument was first calibrated at a temperature of 25 + 0.1° C by exposure to different saturated salt solutions . After calibration, wheat samples were placed into the measuring chamber of the instrument which was connected to a circulating water bath with the temperature set at 25 + 0.1° C . The Aw of sample was read when equilibrium was reached, as noted by no change in the reading over a one hour period (Labuza et al., 1985).

Free fatty acids

The content of free fatty acids was determined using the A.A.C.C. method 02-02A .

Mold count

The number of molds per gram of wheat are determined using the serial dilution method in 0.9% NaCl solution containing 0.01% Tween 80, and the cultivation was made on Potato Dextrose Agar at 25° C for 4 to 5 days. The number of thalli were counted and reported on a one grain sample basis (Mislivec & Bruce, 1977).

Mixograph test

The Swanson-Working Mixograph (30 g version, National Mfg-Co., Lincoln, Nebraska, U.S.A.) was used . 30 grams of flour were used in every test. The test was conducted as described by Finney and Shogren (1972) .

The flour used for mixographic studies was obtained as follows : Wheat samples were conditionned to 17% moisture content . After at least 24 hours of rest, wheat was milled in a Brabender Experimental Mill (Quadrumat junior) .

Falling number test

This test evaluates amylasic activity by rapid gelatinisation of flour particles suspended in water, and subsequent measurement of degradation of the starch paste by alpha-amylase, under conditions similar to those encountered in practice (Perten, 1964); the procedure used is the A.A.C.C. method : 56-81B .

RESULTS AND DISCUSSIONS

Moisture content, water activity, and mold count

An irregular increase in moisture content and water activity occurred over time of storage, in all pit positions, regardless of the type of lining material used (Table I) . Moisture content and water activity of the samples from straw-lined pits were higher than those recorded in wheat samples from plastic-lined pits (Fig. 2 & 3) . Liner type, storage duration, and sampling position affected significantly moisture content and water activity values (Table II) . After 16.5 months of storage in plastic-lined pits, moisture content was kept below 14%, While in pits lined with straw, moisture exceeded 16 % .

Overall moisture and water activity mean values of straw-and plastic-lined pits were significantly different (Table III) . This clearly shows that plastic liner can protect the grain from additional moisture uptake .

High moisture levels promote fungal growth (Shearer & Warwick, 1983 ; Sauer, 1988) . For straw-lined pits, the correlation between moisture content and fungal growth was highly significant (r = 0.72, Table IV) . Such correlation was not recorded in pits lined with plastic where fungal growth stayed at a relatively low level . This is probably because plastic-lining improved the hermeticity of the pit and limited moisture movements in the system which disturbed somehow fungal growth (Fig. 2 & 4) .

Variations of mold count in both types of pits were not similar . They could have resulted, because of mirtight conditions, from the fact that oxygen supply was not low enough to help reduce the mold count, especially in straw-lined pits where a steady increase in the number of mold colonies was noted (Fig. 4) . This may be due to recorded high moisture levels, since moisture content and mold count were significantly correlated in these pits .

Free fatty acids

After three months of storage, the content of free fatty acids increased considerably (Table I, Fig. 5) . Fat acidity level (76 mg. KOH / 100 g solids) in pits lined with straw was about double of that recorded in plastic-lined pits (43 mg. KOH/100 g solids) . This could be due to the increase in mold count which was multiplied by about 400 in the case of straw-lined pits, and by almost 20 in the case of pits lined with plastic (Table V) .

Fig. 1 : Schema of a typical underground pit with 1, 2, 3, and 4 indicating sampling positions.

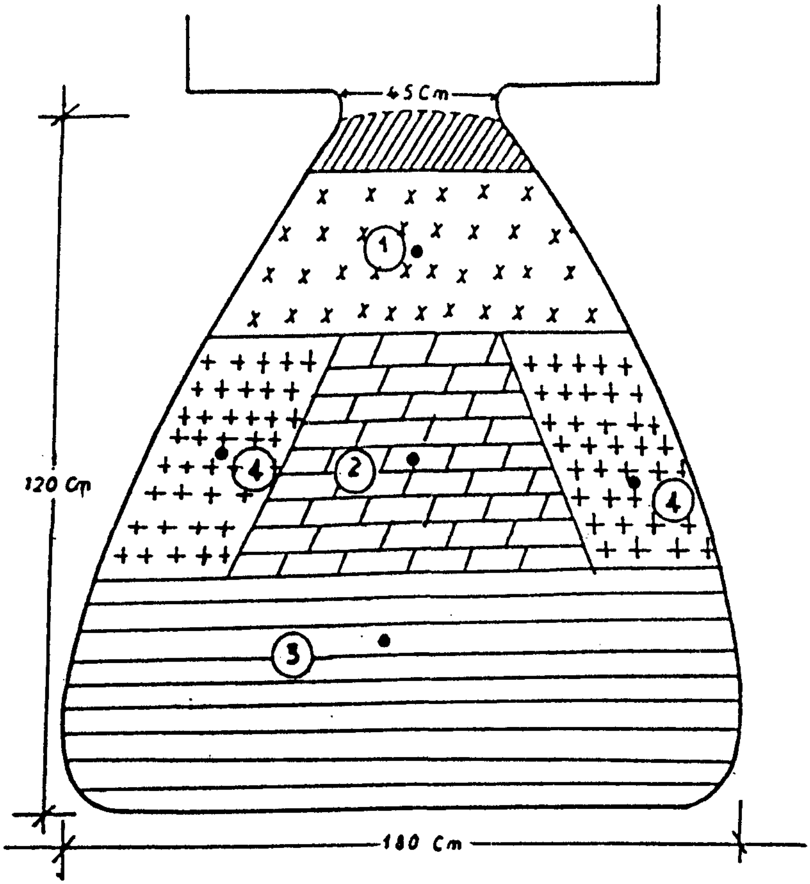


Table I : Moisture content, water activity, and fat acidity of wheat stored in plastic-lined pits and straw-lined pits as a function of storage time and sampling position .

Storage duration (months)	Sampling position	Pits lined with plastic (1)			Pits lined with straw (1)		
		MC	aw	FA	MC	aw	FA
0	(*)	11,02	0,60	16	11,02	0,60	16
3	1	12,29	0,69	36	16,16	0,82	87
	2	12,17	0,67	61	15,79	0,80	57
	3	11,93	0,66	39	16,97	0,82	67
	4	12,14	0,67	35	16,50	0,85	93
	average	12,13	0,67	43	16,36	0,82	76
6	1	12,15	0,67	29	14,80	0,78	35
	2	12,03	0,66	26	14,37	0,77	35
	3	11,94	0,66	28	16,40	0,82	37
	4	12,04	0,66	30	14,34	0,77	33
	average	12,04	0,66	28	14,98	0,79	35
9	1	12,00	0,69	104	14,50	0,80	126
	2	11,90	0,67	92	13,65	0,76	115
	3	12,85	0,72	95	16,65	0,85	112
	4	11,85	0,67	115	14,45	0,79	110
	average	12,15	0,69	102	14,81	0,80	116
16,5	1	13,00	0,70	36	16,55	0,81	153
	2	14,15	0,71	32	16,80	0,78	160
	3	14,95	0,72	27	20,80	0,82	172
	4	13,70	0,70	40	18,75	0,79	160
	average	13,95	0,71	34	18,23	0,80	161

(1) : each value is a mean of two determinations recorded in two identical pits and opened at the same time .
MC : moisture content (g H20 / 100g sample) ; aw : water activity;
FA : fat acidity (mg K0H / 100 g solids) .
(*) : average of 15 determinations .

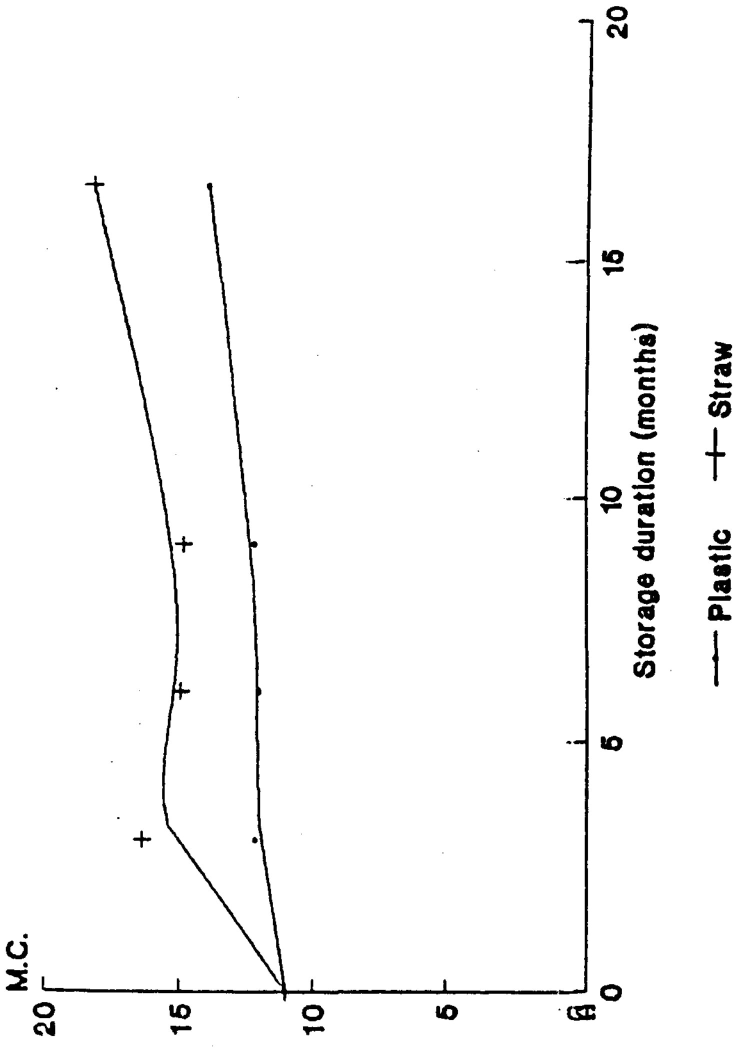


Fig. 2 : Effect of storage duration and liner type on moisture content (MC) of wheat grain.

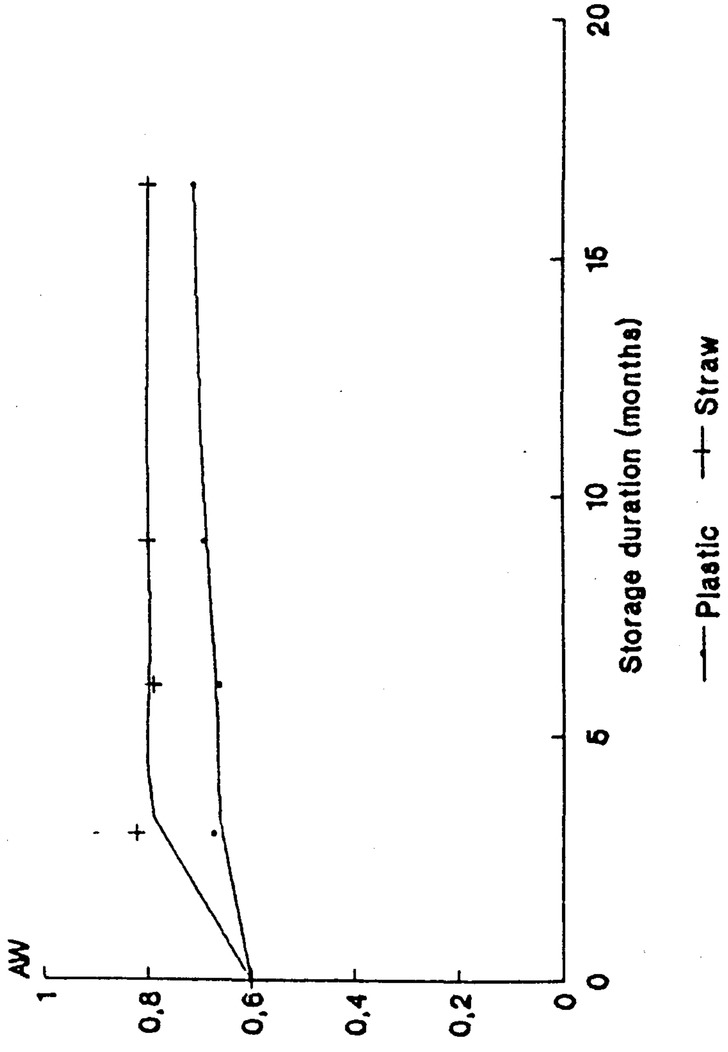


Fig. 3 : Water activity (Aw) changes over time of wheat grain stored in plastic- and straw-lined pits.

Table II : **Three-way analysis of variance showing the effects of storage duration type of internal pit liner, sampling position, and their interactions, on all the parameters determined .**

Variables	Lining (L)		Duration (D)		Position (P)		L * D		L * P		D * P		L * D * P	
	Effect (1)	% (2)	Effect	%	Effect	%	Effect	%	Effect	%	Effect	%	Effect	%
MC	S***	32,51	S***	43,46	S***	3,61	S***	9,92	S**	1,68	S*	3,31	NS	-
aw	S***	32,69	S***	48,08	S*	1,92	S***	9,62	NS	-	NS	-	NS	-
FA	S***	14,23	S***	55,62	NS	-	S***	23,72	NS	-	NS	-	NS	-
MT	S***	25,87	S***	32,34	S*	2,14	S***	21,77	NS	-	NS	-	NS	-
PH	S***	8,60	S***	58,60	NS	-	S***	11,47	NS	-	NS	-	NS	-
WA	S***	18,54	S**	16,26	NS	-	S***	22,11	NS	-	NS	-	NS	-
FN	NS	-	S**	16,69	S*	10,03	NS	-	NS	-	NS	-	NS	-
LogN	S***	45,68	S***	11,73	NS	-	S***	17,70	NS	-	NS	-	NS	-

MC : moisture content; aw : water activity; FA : fat acidity; MT : mixing time; PH : peak height; WA : weakening angle; FN : falling number; log N : logarithm of mold count .
(1) : significant (S) or not (NS) at 95 % (*), 99 % (**), and 99,9 % (***) probability levels .
(2) : % variability of a given parameter explained by a given factor. These effects are calculated from variance analysis tables as follows : (SS (factor) / SS total) x 100 . The residual SS (unknown factors) completes the % effects to 100 % for each variable .

Table III : **Mean values comparison using the Fisher's least significant difference (LSD) method .**

Variance factor	Variables							
	M.C.	Aw	F.A.	M.T.	P.H.	W.A.	F.N.	Log (N)
Storage duration	11,02 D1	0,60 D1	16 D1	3,8 D1	2,8 D2	2,0 D4	452 D5	2,97 D1
	13,48 D4	0,73 D3	32 D3	5,9 D2	3,0 D3	2,1 D5	576 D3	3,36 D3
	13,51 D3	0,75 D2	60 D2	6,2 D3	3,1 D1	2,3 D2	628 D2	3,75 D4
	14,25 D2	0,75 D4	98 D5	8,2 D4	3,2 D4	2,4 D3	663 D1	4,33 D2
	16,09 D5	0,76 D5	109 D4	9,8 D5	3,9 D5	2,7 D1	674 D4	4,59 D5
Position	13,31 P1	0,70 P2	- (1)	6,3 P1	-	-	519 P3	-
	13,34 P2	0,71 P4	-	6,3 P2	-	-	599 P4	-
	13,63 P4	0,72 P1	-	7,0 P4	-	-	643 P2	-
	14,41 P3	0,73 P3	-	7,5 P3	-	-	687 P1	-
Lining	12,26 L1	0,67 L1	44 L1	4,9 L1	3,0 L2	2,0 L2	- (2)	2,64 L1
	15,05 L2	0,76 L2	81 L2	8,6 L2	3,3 L1	2,6 L1	-	4,98 L2

M.C.: Moisture content; Aw: Water activity; F.A.: Fat acidity; M.T.: Mixing time; P.H.: Peak height; W.A.: Weakening angle; F.N.: Falling number; N: Mold count. D1: 0 months; D2: 3 months; D3 : 6 months; D4: 9 months; D5: 16,5 months;
L1: plastic lining; l2:straw lining. Means grouped in one bracket are not significantly different from each other .
(1) , (2) : Hypothesis of equal means not rejected at 95 % probability level .

Table IV : **Correlation coefficients between chemical and physico-chemical properties of wheat grain stored in underground pits (n=17) .**

Properties	Moisture content	Water activity	Fat acidity	Mixing time	Peak height	Weakening angle	Log (mold count)
Straw-lined pits							
moisture content							
water activity	0,70 **						
Fat acidity	0,64 **	0,40					
Mixing time	0,69 **	0,37	0,81 **				
Peak height	0,20	- 0,19	0,51 *	0,34			
Weakening angle	- 0,67 **	- 0,44	- 0,82 **	- 0,92 **	- 0,25		
Log (mold count)	0,72 **	0,53 *	0,52 *	0,57 *	0,37	- 0,51 *	
Falling number	- 0,69 **	- 0,20	- 0,33	- 0,53 *	- 0,01	0,43	- 0,35
Plastic-lined pits							
moisture content							
water activity	0,82 **						
Fat acidity	- 0,17	0,25					
Mixing time	0,30	0,52 *	0,50 *				
Peak height	0,76 **	0,59 *	0,05	- 0,05			
Weakening angle	0,44	0,27	- 0,48 *	- 0,35	0,45		
Log (mold count)	0,15	0,19	0,11	- 0,12	0,18	0,19	
Falling number	- 0,81 **	- 0,57 *	0,32	- 0,32	- 0,49 *	- 0,37	0,12

* and ** : Significant respectively at 95 % ($r \geq 0,48$) and 99 % ($r \geq 0,61$) probability levels .

Fig. 4 : Effect of storage time and lining material on mold count (N) of stored wheat grain.

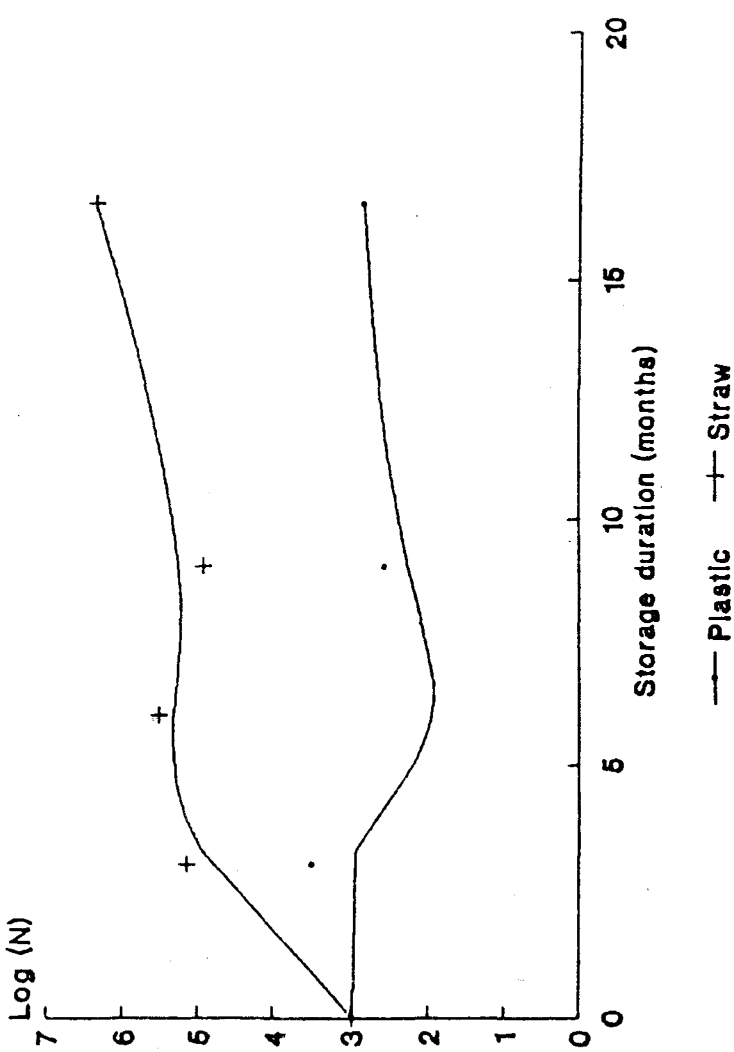
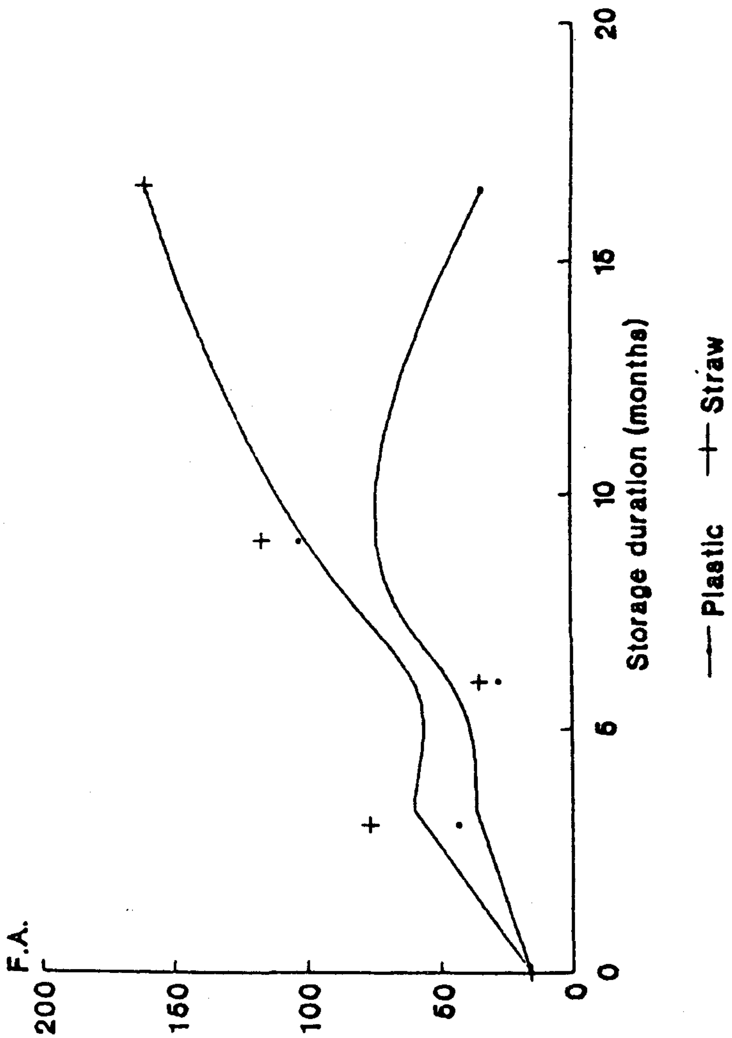


Fig. 5 : Effect of storage duration and liner type on fat acidity (F.A.) of wheat grain.



Fat acidity has attained extremely high levels in straw-lined pits after 16.5 months of storage . Such high values (about 160 mg KOH / 100g solids) have been reported in the literature (Girish et al., 1972) . Sampling position does not affect significantly fat acidity values (Table II) . The concomitant change of fat acidity and mold count was also reported by Daftary & Pomeranz (1965), and was explained by the fact that lipid hydrolysis is mainly catalyzed by microbial lipases . Moisture content variation in straw-lined pits is also closely related to fat acidity fluctuations(r= 0.64). Evidently, plastic liner protected the grain from being seriously deteriorated by limiting significantly fat hydrolysis . Many reports have indicated that the content of fat acidity increases with increasing storage time (Daftary et al., 1970 a ; Girish et al., 1972 ; Fellers & Bean, 1977; Warwick et al., 1979 ; Galliand, 1983 ; Leelavathi et al. , 1984) . For both types of pits, fat acidity values reached already over 20 mg KOH after three months of storage . The level 20 was considered by some authors to be the maximum value found in sound wheat (Fellers & Bean, 1977) . In Moroccan context, we think that this level is quite low.

Mixograph parameters

Mixograph results (Table V) showed that the peak height did not change significantly for up to 9 months of storage regardless of the liner type . From 9 to 16.5 months, it increased by about 20 to 40% . This quality parameter expresses the consistency of dough and its resistance to extension, and has been shown to be sensitive to storage time and pit liner type (Table II) .

These results agree, in essence, with the data reported by Leelavathi et al. (1984) .

Mixing time has increased slightly in both types of pits (Table V, Fig. 6) . Wheat from pits lined with straw gave flour doughs of high development times. The increase in mixing time, over time of storage, has been reported by several authors (Daftary et al., 1970b ; Pomeranz et al., 1968) . Mixing time varied with storage duration, type of liner, and sampling position. As for all the parameters previously discussed, storage time is the factor that explained a high percentage of mixing time variations (Table II) .

Weakening angle values were significantly affected by storage time and the type of lining material . These two factors as well as their interaction explain most of weakening angle variations (Table II) . Weakening angle of flour doughs decreased with storage duration for both types of storage conditions. The decrease is more rapid for wheat stored in pits lined with straw than in plastic-lined pits. After 16.5 months of storage, the weakening angle in straw-lined pits reached half the value obtained in pits lined with plastic.

Significant correlations were found between moisture content (or water activity) and dough mixing time in both types of pits (Table IV) . Signifiant corrrelations were also found between peak height and moisture content but only for pits lined with plastic. Other significant correlations were found between fat acidity and mixing time (r = 0.81 for pits lined with straw, and r = 0.50 for plastic-lined pits), and between fat acidity and weakening angle (r = -0.82 for sraw-lined pits and r = -0.48 for plastic-lined pits) .

Table V : **Effect of storage duration, liner type, and sampling position on mixograph, falling number, and mold count measurements of wheat stored in underground pits .**

Storage duration (months)	Sampling position	Pits lined with straw (1)					Pits lined with plastic (1)				
		M.T. (min.)	P.H. (cm.)	W.A. (°)	F.N. (sec.)	Log (N)	M.T. (min.)	P.H. (cm.)	W.A. (°)	F.N. (sec.)	Log (N)
0	(*)	3,8	3,1	2,7	663	2,97	3,8	3,1	2,7	663	2,97
3	1	6,0	2,8	2,4	587	5,94	5,0	2,7	2,7	608	4,60
	2	6,9	2,4	1,8	602	4,54	5,3	3,0	2,5	710	3,57
	3	7,3	2,8	2,5	586	4,96	5,1	2,9	1,9	623	2,29
	4	6,4	2,9	1,8	612	5,16	4,5	3,0	2,9	695	3,59
	Mean	607	2,7	2,1	597	5,15	5,0	2,9	2,5	659	3,51
6	1	7,6	3,0	2,2	723	5,18	4,8	2,9	2,2	529	1,19
	2	6,1	3,1	2,5	784	5,74	5,5	2,7	2,6	551	1,35
	3	7,9	2,7	2,2	647	5,47	5,4	3,0	2,3	643	1,04
	4	7,4	3,0	2,2	655	5,70	4,8	2,8	2,8	599	1,22
	Mean	7,3	3,0	2,3	702	5,52	5,1	2,9	2,5	450	1,20

9	1	8,9	2,9	1,6	1044	4,74	5,9	3,5	2,5	739	2,30
	2	9,0	3,2	2,0	761	4,55	5,4	3,4	2,1	586	2,92
	3	14,1	2,7	1,1	496	5,38	6,6	3,2	2,4	495	2,44
	4	10,0	2,7	2,0	576	5,05	5,4	3,4	1,9	696	2,59
	Mean	10,5	2,9	1,7	719	4,93	5,8	3,4	2,2	629	2,56
16.5	1	13,6	3,6	1,4	724	5,09	4,0	4,4	3,4	540	2,94
	2	11,4	3,8	1,5	777	7,21	4,9	4,3	3,2	372	1,97
	3(**)	14,5	3,5	1,2	67	6,30	6,5	4,2	2,8	264	3,17
	4	18,5	3,0	0,7	265	6,75	4,5	4,3	2,5	607	3,26
	Mean	14,5	3,5	1,2	458	6,34	5,0	4,3	3,0	446	2,84

(1) : Each number is a mean of two values recorded in two pits identically lined and opened at the same time .

(*) : The values are a mean of 15 determinations .

(**) : The mixograph parameters relative to position 3, for straw lined pits after 16.5 months of storage, were very difficult to measure from the curve. For statistic computations and curve drawings, the values were estimated as being the mean value for the other 3 positions at the same storage duration .

M.T.: mixing time; P.H.: peak height; W.A.: weakening angle; F.N.: falling number;

N : number of mold colonies / g of sample .

The negative correlations between the amount of free fatty acids and mixograph weakening angle were unexpected since the deterioration of dough quality by fatty acids should normally enhance the weakening angle, since lipid hydrolysis would contribute in having doughs of poor rheological properties. Probably the extension of mixing times resulted in fairly flat curves whose weakening angles were low. In fact a negative and highly significant correlation was found between mixing time and weakening angle ($r = -0.92$) in straw-lined pits . The positive correlation between fat acidity and mixing time would mean that probably lipid hydrolysis by itself and the presence of fatty acids in the system prevented dough from being optimally developped in reasonable times . Figures 7a, 7b, and 7c show an extreme situation where dough rheology has been practically and totally impaired. The very strong oscillations at the beginning of the curve may indicate that proteins have been depolymerized as suggested by Hoseney et al. (1966). Isolation of gluten by hand-washing from flours, obtained after milling highly damaged wheat has been very difficult, probably because proteins have lost their basic rheological properties . Gluten yield was low, and protein fractionation of the highly damaged flour showed that water soluble proteins increased considerably whereas acid soluble proteins decreased to a low level (data not shown) . These results agree with those reported by Daftary et al. (1970b) . It is more likely that these rheological changes resulted from extensive hydrolysis of both proteins and lipids .

Falling number

Falling number data were reported in Table V . Variance analysis shows that this quality parameter is not sensitive to the liner type but quite sensitive to sampling position, storage duration, and their interaction (Table II) . Despite the changes recorded in amylase activity, all wheat samples stayed hypodiastasic during the first 9 months of storage . From 9 to 16.5 months, falling number decreased significantly, especially for wheat grain samples from the middle (sides) and the bottom of the pits (positions 3 and 4) . Variations in amylase activity were negatively and significantly correlated with moisture uptake in both types of pits (table IV) .

These results indicate that alpha-amylase activity starts to change significantly after about one year of storage . This period is much shorter than the one indicated by Pixton et al. (1975) .

GENERAL CONCLUSIONS

Significant quality changes have taken place in wheat grain stored in underground pits lined with both plastic and straw . For straw-lined pits, a one year storage period appeared to be the limit not to be exceeded if serious quality changes are to be avoided . However, for pits lined with plastic, the deterioration has been limited even after a one year storage period .

Plastic-lining was much better than straw-lining in terms of preserving much of the initial properties of wheat . It requires a very low investment and allows the farmer to avoid important quality losses .

Fig. 6 : Effect of storage duration and liner type on flour mixing time (M.T.).

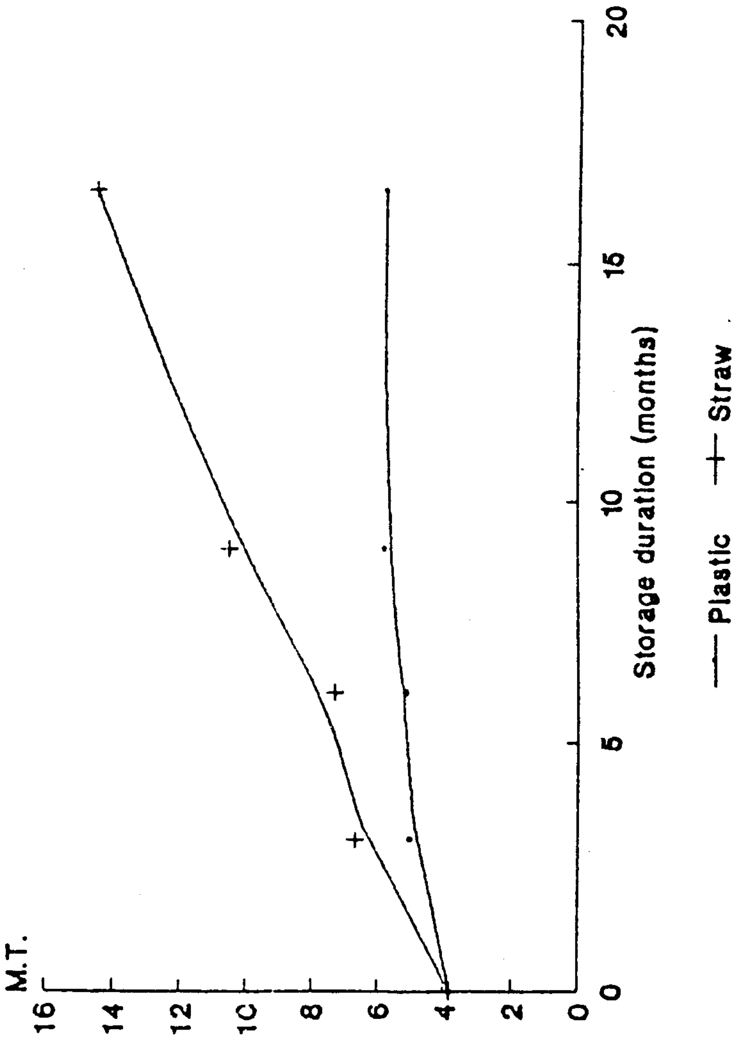
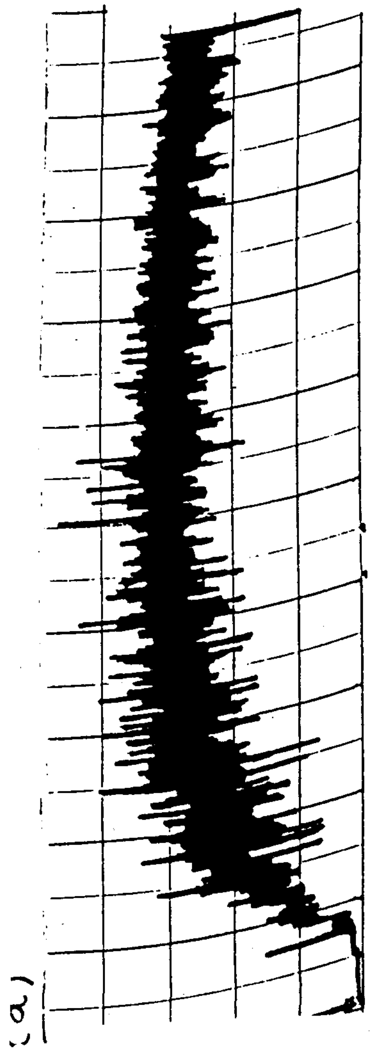
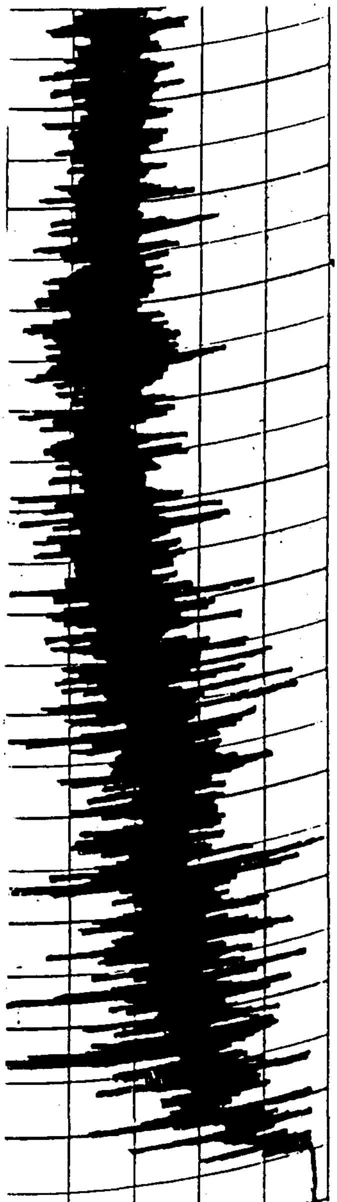


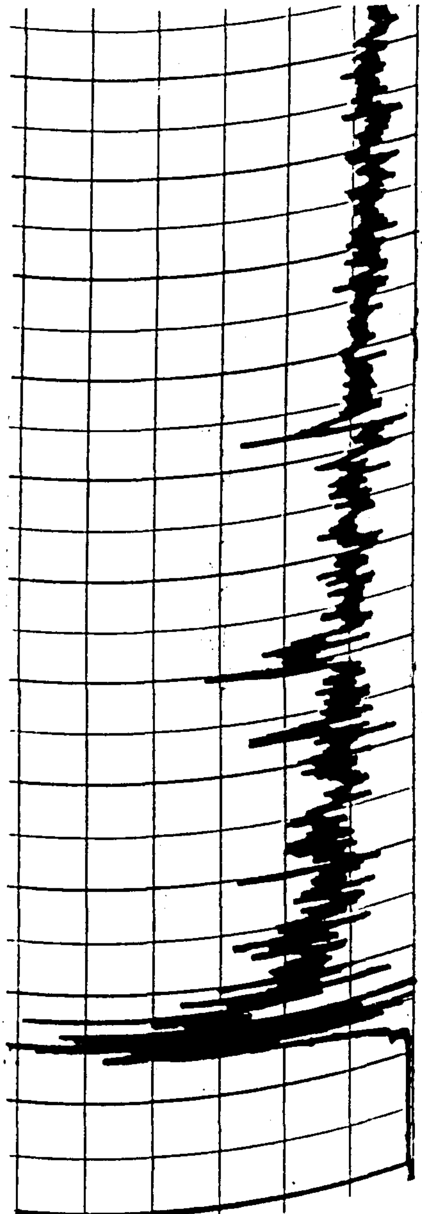
Fig. 7 : Effect of storage time and liner type on wheat mixograms :

a : Test wheat,
b : Wheat stored for 16,5 months in plastic-lined pits,
c : Wheat stored for 16,5 months in straw-lined pits.





(b)



(c)

ACKNOWLEDGMENTS

Financial assistance from AID Washington (AID Science Advisor Grant, Underground Grain Storage Project, Grant N DPE 5542-G-SS-7030-00, Project Number 7336) is gratefully acknowledged . This study was part of a multidisciplinary investigations on underground storage conducted at I.A.V. HII, Rabat, Morocco.

We thank Mr. Allal Hammouda and Ahmed Goumari (Department of Applied Statistics, I.A.V. Hassan II) for their advices .

We also thank Dr. T.P. Labuza (University of Minnesota, St. Paul, MN, U.S.A.) for his helpful comments .

We also thank Dr. Abdelghafour Tantaoui-El Araki (Microbiology Department, I.A.V. Hassan ii) for providing us mold count values.

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