QUALITY OF PADDY STORED IN UNDERGROUND SILOS
PART I

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ABSTRACT

Paddy, variety IAC 4440 sun dried to average moisture contents of 15.0%, 14.1% and 12.1%, was bulk stored in 27 small (60kg) underground polyethylene silos. Samples were taken initially and after 2, 4 and 6 months of storage.

The quality changes during storage were evaluated by the following tests: moisture content, water activity, free fatty acid content, insect infestation, fungal infection, vitamin B1 content, viscosity and flavour.

Measurements of the temperature and carbon dioxide and oxygen contents inside the silos were made at periodic intervals.

After six months of storage, the analyses showed minimum variations in moisture content, water activity, free fatty acid contents and flavour. There was a complete absence of insects, and a slight reduction in the level of vitamin B_1 in the polished rice. However an accentuated increase in species of A. glaucus group was found in the paddy with a moisture content of 14% and an even greater increase in that with 15% of moisture. This increase was not followed by changes in colour, flavour and free fatty acid content. In the samples with 15% moisture content, the cold viscosity decreased and the hot viscosity increased.

After 6 months of storage the CO_2 contents were 6.0%, 7.7% and 8.6%, and the O_2 contents 15.9%, 13.2% and 10.3% respectively, in the silos at 12 %, 14% and 15% moisture contents.

The results indicated that the underground silo studied was a feasible alternative for the storage on non-infested paddy with a moisture content of up to 15%, and for a period of six months.

INTRODUCTION

Since 1973, the brazilian Institute of Food Technology (ITAL - Campinas) has been working with underground silos, and the results of this research have indicated that this technique is a feasible alternative for the storage of maize and dry beans. (Sartori & Costa, 1975; Sartori & Vitti, 1986; Sartori et alii, 1981b; Sartori et alii, 1981c; Sartori et alii, 1985). Maize kept its technological qualities for industrial use (starch isolation, germ, gluten, fiber, processing field) for a period of six months, even when stored with a moisture content of 16.4%. The behaviour of paddy, when stored at different moisture contents in the underground polyethylene silos is unknown, but Wills (1983) during laboratory studies verified that rewetted paddy with a 20% moisture content could be satisfactorily stored for six weeks at 30°C, either in hermetic glass containers or polyethylene bags.

Rice is a basic food item of the brazilian population, and to maintain its quality from production to consumer it is necessary for the product to be quickly dried and stored in adequate structures and conditions after harvest.

In the underground polyethylene silos its is possible to store grain at low cost under a modified atmosphere and thus this could be a solution in those areas where it is difficult to dry paddy up to a moisture level considered safe for storage, and also where there is no infra structure for grain storage.

The objective of this research was to verify the performance of rice, when stored in bulk as paddy in underground polyethylene silos, with average moisture contents of 12, 14 and 15% for a period of six months.

MATERIAL AND METHODS

Paddy, variety IAC 4440, was sun dried to three different moisture contents and stored in 27 small underground polyethylene silos (capacity of 60kg). Nine were used to store paddy having a moisture content (m.c.) of 12.1%, nine held paddy at 14.1% m.c. and nine at 15.0% m.c. The structure were constructed following the steps depicted in Figure 1.

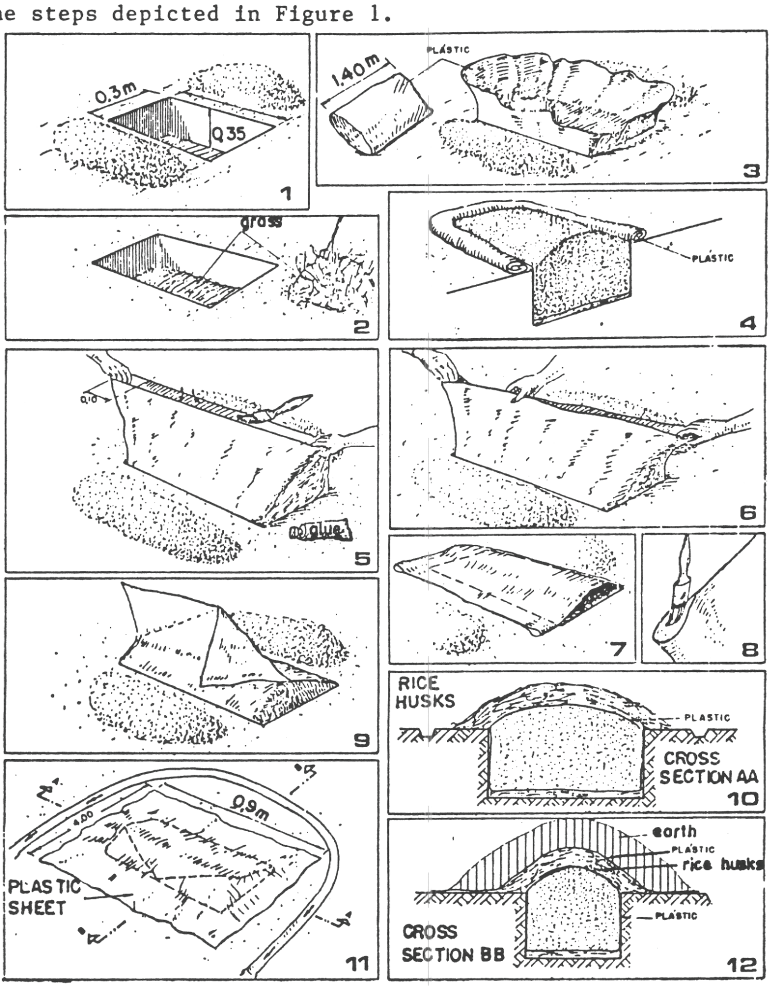


FIGURE 1. Underground polyethylene silos
SOURCE: Instituto de Tecnologia de alimentos e Coordenadoria de Assistência técnica Integral, s.d.

Samples were taken initially and at intervals of two, four and six months, by opening nine silos after each period of storage (three for each moisture content).

The quality of the product was evaluated by submitting the samples to the following tests:

Moisture content: This was determined according to the official American Association of Cereal Chemists method 44-15A (A.A.C.C., 1976).

Water activity: Values of water activity were obtained by using the NOVASINA apparatus.

Free fatty acid content: The F.F.A. contents were determined according to the official American Oil Chemists' Society Method A.O.C.S. CA 5A-40 with the following modifications. The oil was extracted by placing the triturated material together with the petroleum ether (p.e. 30 to 60°C) in a shaker, and the solvent residue was eliminated by means of a nitrogen flow.

Insect infestation: Samples of approximately 1kg were sifted and examined in order to detect the presence of insects. Internal infestation by species of Sitophilus was verified by the Frankenfeld Method (Frankenfeld, 1948).

Internal Infection by fungi: This was determined by the methodology indicated by Phillips (1987) and described by Penteado (1990).

Vitamin B_1 content: Determination of vitamin B_1 content in the polished rice were carried out according to the fluorimetric method (Strochecker & Henning, 1967).

Viscosity: The values for hot viscosity and cold viscosity were obtained by the method indicated by Vitti (1990) and described by Penteado (1990).

Flavour: The methodology described by Kramer & Twigg (1970) was used.

Carbon dioxide and oxygen measurements were determined periodicalyy by using a gas chromatograph and ORSAT gas analyser. The samples were taken using the apparatus shown in Figure 2, which was connected to copper tubes placed inside the silos. Temperature measurements were made using thermocouples positioned in the same places used for taking gas samples. Atmospheric temperature was recorded by a thermograph placed in a metereological shelter located nearby.

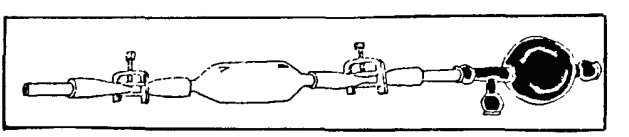


FIGURE 2. Apparatus used for gas sampling

RESULTS AND DISCUSSION

The results of the various tests carried out are indicated in Tables 1 to 7 and in Figures 1 to 6

After two months of storage there was a slight reduction in the moisture content of the paddy. The permeability of the polyethylene associated to the vapor tension between the interior and exterior of the silos would not explain this decreased according to the data obtained by Garcia (Garcia et alii, 1989). The dry weather condition exiting at the establishment of the experiment probably account for the difference in the moisture equilibrium of the grains between the initial figures and those after two months. After that period the values remained pratically enchanged indicating that there was no penetration of water (Table 1).

TABLE 1. Average values for moisture content of paddy stored in underground silos

Moisture content	Period of storage (months)				Averages
	0	2	4	6	
12%	12,1	11,7	11,7	11,8	11,8A
14%	14,1	13,7	13,7	13,8	13,8B
15%	15,0	14,6	14,7	14,7	14,7C
Averages	13,7a	13,3b	13,4b	13,4b	13,4

In can be seen from Figure 3 that there was practicallly no difference in the performance of the silos with different moisture contents with respect to temperature. During the first week of storage the values decrease from 27.4°C to approximately 19.5°C. The temperature inside the silos accompained the variation in ambient storage temperature although the range of thermal variation inside the silos was lower tham that observed in the environment (Figure 4).

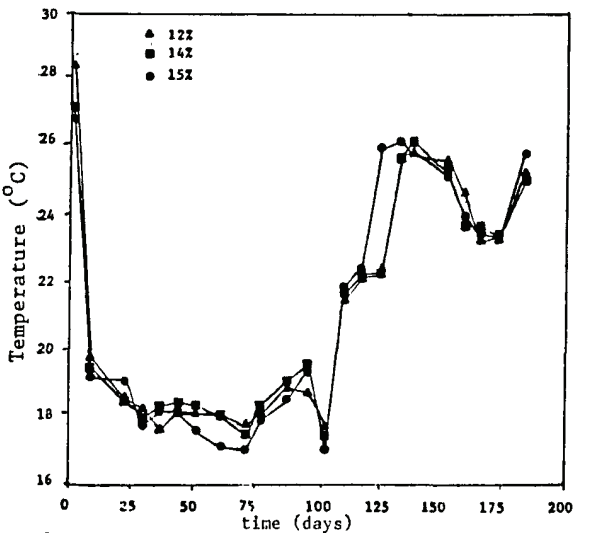
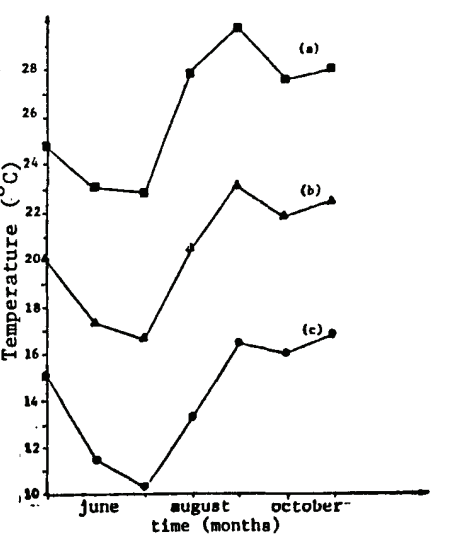


FIGURE 3. Variation with time of the temperatures inside underground silos containing paddy stored in bulk at different moisture contents.



(a) maximum average temperature

(b) average ambient storage temperature

(c) minimum average temperature

FIGURE 4. Variation in average ambient storage temperature during the experimental period

The changes in the values for water activity (Figure 5) of the paddy at different moisture contents were probably due to the alterations in temperature that occured within the silos during the storage period since there was no significant difference in the moisture contents after the storage period of two months.

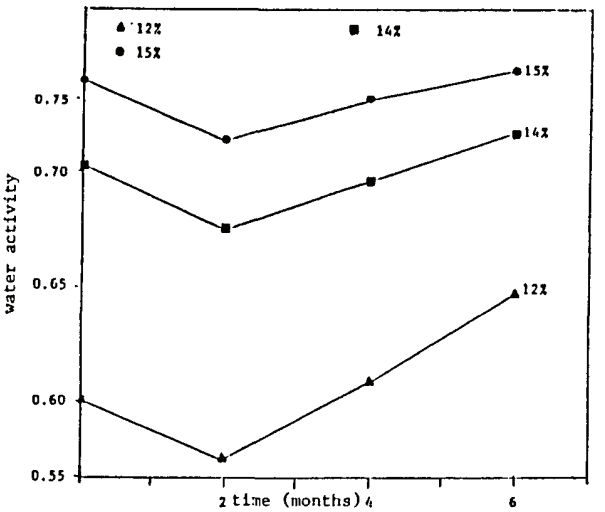


FIGURE 5. Average values for water activity of paddy stored in underground silos

With respect to the CO_2 and O_2 contents (Figure 6) it can be seen that the decreases in O_2 concentration were accompanied by increases in CO_2 contents. After six months of storage the CO_2 and O_2 contents were still not stabilized, showing a tendency to increase in CO_2 and decrease in O_2 at all moisture contents. The changes in CO_2 and O_2 concentrations are affected by the temperature, moisture, microorganisms associated with the grains (Cristensen, 1982; Hyde et alii, 1973; Diawara et alii, 1986) and by the product itself.

After 100 days of storage, an increase in ambient temperature corresponded to a variation in behaviour between the samples at different moisture contents with respect to CO_2 production and O_2 consumption.

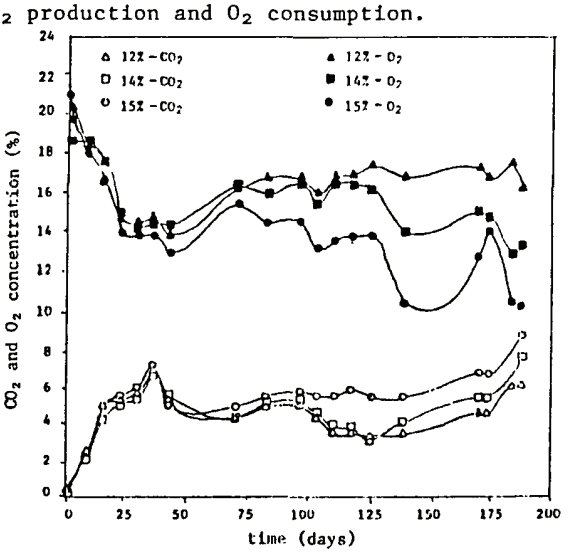


FIGURE 6. Average concentrations of CO_2 and O_2 in the underground silos

From Table 2 it can be observed that the free fatty acid contents of the paddy with 14 and 15% moisture contents did not differ from each other, but they did differ from the paddy with a 12% moisture content. The average values did not change significantly with storage time with the exception of two month sampling period.

TABLE 2. Average values for free fatty acid content of paddy stored in underground silos

Moisture content	Period of storage (months)				Average
	0	2	4	6	
12%	1,59	1,61	1,66	1,66	1,63A
14%	1,68	2,25	1,79	1,91	1,91B
15%	1,74	2,43	1,97	1,93	2,02B
Averages	1,67a	2,10b	1,81a	1,83a	1,85

The presence of storage grain insects was not detected either initially or during the storage period. No internal infection by species of Sitophilus was determinated.

The percentage of grain internally infected by fungi in the samples taken initially and at the end of each storage period are shown in Table 4. When the MY 40G medium was used a high percentage of infection by fungi of the A. glaucus group was observed for the paddy stored at 15% moisture content after a storage period of four months and for the paddy stored at 14% moisture content after a storage period of six months. The invasion of grains by storage fungi is also influenced by the temperature, storage time and CO_2 concentration, and especially by the O_2 concentration in the intergranular atmosphere (Calderon, 1981; Magan & Lacey, 1984; Magan & Lacey, 1988; Hyde et alii, 1973). The percentage of grains internally infected by fungi of the A. flavus group, a potentially toxigenic species remained relatively low and constant. The results obtained using the $GMYE^+$ medium indicated no significant alteration during the storage period.

TABLE 3. Percentage of paddy grains internally infected by fungi as detected by the direct plating method on MY40G medium

Fungi	Period of storage (month)											
	0			2			4			6		
	Moisture Contents											
	12%	14%	15%	12%	14%	15%	12%	14%	15%	12%	14%	15%
Aspergillus glaucus g	1	-	1	1	1	1	-	-	62	1	22	75
Aspergillus flavus g	8	5	12	2	1	2	6	9	3	9	2	3
Aspergillus niger g	-	-	-	-	1	-	-	-	-	-	-	-
Aspergillus sp	1	1	1	-	3	15	-	1	1	-	1	4
Penicillium sp	-	1	-	-	-	-	-	1	-	-	-	-
TOTAL	10	7	14	3	6	18	6	11	66	10	25	82

No significant difference was observed during the period of storage between the samples of different moisture content with respect to the vitamin B_1 content of the polished rice (Table 4). After six months of storage, a significant decrease in the vitamin B_1 content of the polished rice was noted in all samples. From the end at the first week up to the completion of four

months of storage the temperature of the silos was, on average, below 22.4°C. The temperature rise that occurred after the fourth month of storage might have resulted in the vitamin B_1 degradation in the polished rice, observed at the end of the storage period.

TABLE 4. Average values for vitamin B1 of the polihed rice (mg/100g) stored as paddy in underground silos.

Moisture content	Period of storage (months)				Averages
	0	2	4	6	
12%	0,15	0,15	0,14	0,10	0,14A
14%	0,12	0,13	0,13	0,06	0,11A
15%	0,14	0,11	0,12	0,06	0,11A
Averages	0,14a	0,13a	0,13a	0,07b	0,12

For the paddy stored with 15% moisture content, an increase in the hot viscosity (Table 5) and a decrease in the cold viscosity (Table 6) were observed after six months of storage, in previously obtained values. This indicated that the product, after coolling, would become less viscous. The same behaviour was not verified for the paddies with 12 and 14% moisture contents. According to Sartori et alii (1978) low storage temperatures immediately after harvest can retard the desirable reactions (for instance, diminution of the level of cohesiviness) that occured during this period.

Under the experimental conditions the ageing process was retarded for the paddies with 12 and 14% moisture contents, but not with that of 15% moisture content.

TABLE 5. Average values for hot viscosity (B.V.) of the polished rice stored as paddy in underground silos

Moisture content	Period of storage (months)			
	0	2	4	6
12%	500	520	670	660
14%	570	525	740	670
15%	600	565	780	1350

TABLE 6. Average values for cold viscosity (B.V.) of the polished rice stored as paddy in underground silos

Moisture content	Period of storage (months)			
	0	2	4	6
12%	1160	1080	1400	1300
14%	1190	1335	1540	1330
15%	1260	1240	1780	700

The results of the flavour test are shown in Table 7. It can be seen that there was no alteration in the flavour with storage time for the samples of different moisture content. The paddy with a moisture content of 12% differed statistically from the standard and reached an average value inferior to that of the standard sample, but no strange flavour was detected. Is was noted that

the colour of the paddy with 12% moisture content was altered ("fairly yellowed") in comparison to the others. As this lot was submitted to the drying conditions for a longer period, it possible that some chemical change occurred causing alterations in its colour and flavour

TABLE 7. Average values for the flavour test of the polished rice stored as paddy in underground silos.

Moisture content	Time (months)				Averages
	0	2	4	6	
Standard	3.78	3.92	3.82	3.88	3.85A
12%	3.55	3.08	3.36	3.58	3.40B
14%	3.70	3.67	3.61	3.71	3.67A
15%	3.63	3.75	3.51	3.67	3.64A
Average	3.67a	3.60a	3.57a	3.71a	

CONCLUSIONS

The underground polyethylene silo is a feasible technical alternative for the storage of non-infested paddy with a moisture content of up to 15% and for a period of up to six months.

The difference in moisture content did not affect the vitamin B_1 content of the polished rice at the levels studied.

There was no significant alteration in flavour during the storage period for any of the samples, but that with a moisture content of 12% had the worst flavour.

The increase in fungal infection by species of the A. glaucus group was not accompanied by changes in colour, flavour and free fatty acid content.

From the point of view of viscosity, a moisture content of 15% appeared to be the best for a storage period of six months according to the brazilian standard of preference (flufly, less viscose rice).

Suggestions for future research:

1. Test higher moisture contents and/or longer periods of storage than those used in this study.

2. Verify the efficience of this storage method in the control of stored paddy pests.

3. Carry out aflatoxin analyses in the samples that show fungal infection by A. flavus.

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LA QUALITE DU RIZ PADDY (*ORYZA SATIVA*, L.) STOCKE EN ATMOSPHERE MODIFIEE DANS DES CONTENEURS SOUTERRAINS

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RESUME

Du riz Paddy, variété IAC 4440, séché au soleil pour avoisiner une teneur en eau de 15,0 %, 14 % et 12,1 % a été stocké dans 27 petits (60 kg) conteneurs souterrains en polyéthylène. Des échantillons ont été récoltés, avant stockage, puis après 2, 4 et 6 mois de conservation.

Les variations de qualité au cours du stockage ont été mesurées par les tests suivants : teneur en eau, activité de l'eau, contenu en acides gras libres, infestation par les insectes, contamination fongique, teneur en vitamine B1, viscosité et goût.

Des mesures de la température, de dioxyde de carbone ainsi que de la teneur en oxygène ont été faites à intervalles réguliers.

Après 6 mois de stockage, les analyses ont fait apparaître de minimes variations de la teneur en eau, de l'activité de l'eau, du contenu en acides gras libres et du goût. Il n'y avait pas d'insectes et une légère réduction de la teneur en vitamine B1 a été notée dans le riz poli. Cependant, un accroissement du nombre d'espèces du groupe de *A. glaucus* s'est présenté dans le riz Paddy à la teneur en eau de 14 % et un plus grand accroissement encore dans celui ayant une teneur en eau de 15 %. Cet accroissement n'a pas été suivi d'un changement de couleur, de goût ou de contenu en acides gras libres. Dans les échantillons ayant une teneur en eau de 15 %, la viscosité à froid a diminué et la viscosité à chaud augmenté.

Après 6 mois de stockage, les teneurs en CO_2 étaient de 6 %, 7,7 % et 8,6 % et les teneurs en O_2 étaient de 15,9 %, 13,2 % et 10,3 %, respectivement, dans les conteneurs ayant 12 %, 14 % et 15 % de teneur en humidité.

Les résultats ont montré que les silos souterrains étudiés constituent une alternative possible pour le stockage du riz non infesté, avec une teneur en eauidité allant jusqu'à 15 %, pendant une période de 6 mois.