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QUALITY CONSERVATION OF PADDY STORED UNDER GASTIGHT SEAL OUTDOORS IN THE PHILIPPINES

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ABSTRACT

Paddy stacks of capacities ranging from 13.4 to 31.9 t were stored outdoors in flexible enclosures for 78 to 183 d. The quality of the paddy was compared with that of three control stacks (5.3–5.6 t capacity) held under tarpaulins in the open for 78–117 d. The trials were conducted at the NAPHIRE compound, Nueva Ecija, the Philippines. Two varieties of enclosures were tested, heavy-duty PVC-based sheeting sufficiently gastight to control insect infestations (called "Volcani cubes" and designed in Israel for stacked bag storage) and weld-mesh supported silos, in both of which the paddy was stored in bulk. In both systems, the upper layers of paddy were covered with a layer of rice hulls aimed at reducing temperature gradients, and plastic sheeting was placed between this insulating layer and the grain, serving to prevent the transfer of moisture to the top grain layer. Moisture content, grain temperature and gas concentrations were measured throughout the trials. Initial and final samples were taken to determine changes in paddy quality; insect infestation, fungal infection, milling recovery, head rice, yellow kernels, brokens, germination and weight loss were analyzed. The percentage of milling recovery and the levels of yellowing in the gastight stacks showed no significant change. The levels of head rice and brokens were preserved in seven out of nine stacks. A decrease in the percentage of head rice in two stacks was attributed to the biological aging phenomenon. The two control stacks showed a decrease in head rice and an increase in brokens. Rice yellowing was very pronounced in one of the control stacks.

INTRODUCTION

This report forms part of a more comprehensive study designed to provide alternative temporary or emergency outdoor storage facilities for use by farmers' organizations, cooperatives, village grain merchants and other intermediary parties in the Philippines (and other countries) where countryside storage is an important component of the national grain reserve.

The storage facilities used in this project were designed as gastight structures that can provide affordable and user-friendly grain-conservation systems without the need for chemical pesticides. This report describes storage trials with paddy undertaken in the Philippines. It details the storage conditions recorded during the trials and the findings relating to quality conservation, including insect infestation and damage. Other sections of the study have been reported elsewhere (Alvindia *et al.*, 1994; Caliboso *et al.*, 1997).

MATERIALS AND METHODS

The paddy storage trials were conducted at the National Post Harvest Institute for Research and Extension (NAPHIRE) compound, Muñoz, Nueva Ecija, Philippines.

Storage methodology

Descriptions of the storage structures, preparation of the storage site, construction of the stacks, insulation of the stacks, sealing, periodic monitoring of gas compositions within the storage structures and grain sampling methodology are provided in a paper by Caliboso *et al.* (1997).

Quality evaluation

Moisture content (m.c.) was determined by drying grain samples for 1 h in an oven (Anon., 1982). Live insects, sieved from the composite and representative samples, were sorted according to group and species.

Quality parameters were calculated by hand counting the number of insect-damaged, discolored, moldy and germinated kernels in 1,000 kernel samples taken from composite samples. Viability tests were done by the rag-doll method.

Data were statistically analyzed using the Multi-Factor Analysis of Variance (AVMF) and Least Square Difference (LSD) tests.

RESULTS AND DISCUSSION

A total of nine trials were carried out on storage of paddy in plastic Volcani cubes, two in plastic silos and two in control stacks under tarpaulins. Table 1 lists the details and durations of the trials.

Moisture content

The average m.c. of gastight sealed paddy in stacks P2 and P11 increased slightly but significantly from the beginning to end of storage, whereas no significant increase was noted in the rest (Table 2). There was a real trend towards an increase in m.c. in the two control stacks stored during the wet season (P3 and P6) and towards a decrease in m.c. in the control stack stored during the dry season (P9). These differences indicate the importance of the gastight sheet in preventing moisture diffusion. The field trials show that

TABLE 1
List of paddy trials carried out in the Philippines

Trial no.	Stack code	Structure: Cube	Structure: Silo	Treatment: Gas-tight	Treatment: Control	Handling: Sacks	Handling: Bulk	Capacity (t)	Duration of storage (d)
I-1	P1	×		×		×		14.00	94
I-2	P2	×		×		×		13.43	94
I-3	P3	×			×	×		5.30	94
II-1	P4	×		×		×		13.63	117
II-2	P5	×		×		×		13.84	117
II-3	P6	×			×	×		5.30	117
III-1	P7	×		×		×		14.77	78
III-2	P8	×		×		×		15.06	78
III-3	P9	×			×	×		5.56	78
IV-1	P10	×		×		×		14.78	97
IV-2	P11	×		×		×		14.73	97
V-1	P12		×	×			×	31.86	183
VI-1	P13		×	×		×		30.38	43

TABLE 2
Moisture content of composite samples taken from paddy stacks during the trials

Trial no.	Stack code	Treatment	Moisture content: Initial	Moisture content: Final
I-1	P1	Gastight	10.30 a	10.56 a
I-2	P2	Gastight	9.87 a	10.83 b
I-3	P3	Control	9.67 a	11.60 b
II-1	P4	Gastight	11.68 a	12.37 b
II-2	P5	Gastight	12.07 a	12.28 a
II-3	P6	Control	12.15 a	12.80 b
III-1	P7	Gastight	11.16 a	11.27 a
III-2	P8	Gastight	11.61 a	11.07 b
III-3	P9	Control	12.34 a	10.67 b
IV-1	P10	Gastight	12.23 a	13.08 a
IV-2	P11	Gastight	13.46 a	14.24 b
V-1	P12	Gastight silo	10.75 a	10.63 b
VI-1	P13	Gastight silo	18.21 a	14.87 b

In a row, means followed by the same letter are not significantly different at 5% level using LSD test.

there was no critical moisture build-up or localization in any of the treatments and controls with the exception of P11, which exceeded the critical m.c. of 14% by 0.24%. The overall m.c. of paddy stored in bulk under gastight conditions in the silo did not change significantly during the trial (P12). This result suggests the feasibility of bulk storage in the silo without an adverse effect on the m.c. of paddy.

A significant reduction from 18.21 to 14.87% in m.c. of the wet in-silo paddy (P13) was recorded after storage for 43 d. This reduction may be explained by the thermal gradients that caused the mass transfer of moisture. The air movement induced by diurnal temperature differences and the diffusion of moisture as a result of moisture equilibration between the grain and the air both resulted in the air's taking up moisture from the wet paddy, resulting in the formation of dew under the liner during the cool hours of the evening. Water that condensed below the liner was initially absorbed by the rice hulls. This was evidenced by the fact that the rice hulls, which initially averaged 7.97% m.c., more than doubled their m.c. to 18.58% by the end of the 43-d trial. A total of 92 bags of rice hull, each weighing about 5 kg, were used. Most of the rest of the condensed water was apparently absorbed by the upper layer of the grain mass, with some water also accumulating on the thin plastic sheet placed between the rice hulls and the paddy bags. The plastic sheet was provided to catch any condensed water that might have dripped between the sacks of rice hulls, and also to catch any excess moisture that was not absorbed by the rice hulls. This change in m.c. was not reflected in all the grain samples since moisture translocation appears to have been confined to the upper layer. That the weight of the grain changed only very slightly indicates that excess water remained within the stacks and silos.

Gas concentration

Maximum carbon dioxide (CO_2) concentrations recorded in the gastight silos and cubes of paddy are shown in Table 3. The maximum CO_2 concentration, found in the

TABLE 3
Maximum CO_2 concentrations generated in gastight storage cubes containing stored paddy and initial moisture contents

Trial no.	Stack code	Percent CO_2	Initial moisture content
I-1	P1	6	10.30
I-2	P2	7	9.87
II-1	P4	13	11.68
II-2	P5	10	12.07
IV-1	P10	15	12.23
IV-2	P11	18	13.46
V-1	P12	5	10.75
VI-1	P13	19	18.21

silo containing high m.c. paddy, reached 19%. Lower CO_2 concentrations, reported in stacks P1, P2 and P12, were due to leaks in the plastic sheeting caused by insects or mechanical damage. In stack P1, it was discovered only after 6 weeks of storage that the zipper was unlocked. In the first silo trial, P12, there was a heavy infestation by the lesser grain borer. The silo remained unsealed for several days, enabling insects to attack the liner. After the damage to the liner was detected, it was decided to fumigate the bulk with phosphine at a dosage of 6 g/t.

The high CO_2 concentrations recorded in P11 and P13 indicate that the initial m.c. of the commodity caused intensive biogeneration of CO_2 by microorganisms.

Insect infestation

Initial and final counts of live insects revealed no significant population increase in the gastight sealed paddy stacks (Table 4), whereas in the control stacks (P3, P6 and P9) there were marked increases in insect density and many of the insects were still alive at the end of the storage period. These results show that in all the gastight sealed stacks complete disinfestation of paddy was not achieved. In spite of the presence of a few live insects at the end of storage, however, all the treatments in the trials were successful. This is matched by a much lower percentage of weight loss in the treated stacks in comparison with the control stacks.

TABLE 4
Average density of insects per kg of sample in paddy trials

Trial no.	Stack code	Treatment	Insect density: Initial	Insect density: Final	Significance level
I-1	P1	Gastight	5.33 (–)	8.00 (–)	ns (–)
I-2	P2	Gastight	9.67 (–)	1.67 (–)	* (–)
I-3	P3	Control	13.67 (–)	35.33 (–)	ns (–)
II-1	P4	Gastight	8.67 (0)	0.33 (36.33)	** (**)
II-2	P5	Gastight	17.00 (0)	2.33 (63)	* (**)
II-3	P6	Control	16.67 (0)	51.00 (91.00)	ns (**)
III-1	P7	Gastight	0 (18.00)	4.33 (122.67)	** (**)
III-2	P8	Gastight	0 (11.33)	6.67 (26.67)	* (ns)
III-3	P9	Control	0 (12.33)	47.33 (89.33)	** (ns)
IV-1	P10	Gastight	3.33 (0.33)	6.33 (2.67)	ns (ns)
IV-2	P11	Gastight	3.00 (0.33)	0 (4.67)	ns (*)
V-1	P12	Gastight silo	24.67 (18.67)	15.00 (261.67)	ns (**)
VI-1	P13	Gastight silo	10.33 (0)	1.33 (1.00)	** (ns)

ns = not significant; * = significant at 5% level; ** = significant at 1% level.
Numbers represent live insects per kg of sample; numbers in brackets, dead insects per kg of sample.
– = not recorded.

The insect species found in the silo trial of bulk paddy (P12) before storage were a few dead *Tribolium castaneum* and live *Rhyzopertha dominica*, *Sitophilus oryzae*, *Lophocateres pusillus*, *Oryzaephilus surinamensis* and *Carpophilus dimidiatus*. During unloading large numbers of dead insects of various species and live *R. dominica*, *L. pusillus* and *O. surinamensis* were retrieved. The density of live insects at the end of the trial was reduced, whereas an increase was noted in the density of dead insects (Table 4). These results indicate that gastight conditions inside the silo did inhibit insect development but could leave a residual insect population below the economic threshold. Initial flushing with CO_2, however, could be used to control initial infestations.

Paddy qualities

Changes in the percentage of milling recovery of head rice, broken grains and yellow grains in dry paddy are presented in Table 5. Neither the milling yield nor the level of the yellowing grain in the gastight paddy stacks were significantly altered.

In general, gastight storage preserved grain quality by maintaining the level of head rice. The levels of head rice and brokens were preserved in 8 out of 13 stacks while in P1 and P4 a rise in the percentage of head rice was recorded. This may be explained by the biological aging phenomenon which occurs in paddy during the first 3 to 4 months of storage. It is theorized that the aging phenomenon is the result of a sol-gel transformation of colloidal starch and protein deposited during ripening and its transformation into a more stable, water-insoluble physical form during storage. Tensile strength of the grain increases, and this increased hardness is translated into higher total and head rice yields and a greater resistance to milling.

As expected, the two control stacks (P3 and P6) showed a decrease in head rice and an increase in brokens. Because the trial was conducted during the dry season, and due to the short duration of storage, the control stacks for trial P9 did not exhibit severe quality deterioration. Rice yellowing, however, was very pronounced in untreated control stack P3. Although yellowing increased in the wet paddy stack (P13), the final level remained low.

The above data suggest that gastight storage of dried bagged and bulk paddy has no adverse effect on grain yellowing, milling yield and other quality parameters.

Viability

The germination of paddy stored under gastight sealed conditions did not change significantly during the trials (Table 6).

Weight loss

The weight losses observed during the field trials are shown in Table 7. The magnitude of loss recorded from the gastight sealed paddy stacks was about 18 times lower than that in the control stacks and resulted in 3.75–4.85% weight loss.

TABLE 5

Comparison of mean quality parameters in paddy at the beginning and end of storage

Stack code	Treatment	Milling recovery (%)		Head rice (%)		Yellow kernels (%)		Broken kernels (%)	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final
P1	Gastight	68.71	69.67**	75.47	77.27*	0.32	0.26^{ns}	25.43	22.73*
P2	Gastight	69.66	70.16^{ns}	83.20	82.53^{ns}	0.16	0.23^{ns}	16.80	17.46^{ns}
P3	Control	70.33	70.31^{ns}	82.80	78.33*	0.16	4.67**	17.20	21.67*
P4	Gastight	66.12	67.61*	73.60	77.33**	0.27	0.23^{ns}	26.07	22.67^{ns}
P5	Gastight	66.47	65.35^{ns}	72.47	72.47^{ns}	0.33	0.34^{ns}	27.53	26.30^{ns}
P6	Control	66.89	67.00^{ns}	77.73	70.90**	0.33	0.22^{ns}	22.07	20.10^{ns}
P7	Gastight	64.62	63.90^{ns}	76.55	77.71^{ns}	1.00	0.69^{ns}	23.45	22.56^{ns}
P8	Gastight	64.37	64.68^{ns}	81.32	81.81^{ns}	0.08	0.05^{ns}	18.68	18.19^{ns}
P9	Control	64.26	65.57^{ns}	82.61	82.85^{ns}	0.23	0.13^{ns}	17.39	17.19^{ns}
P10	Gastight	64.09	63.15^{ns}	82.24	74.64*	0.07	0.16^{ns}	17.76	24.70*
P11	Gastight	62.96	61.85^{ns}	81.74	77.24^{ns}	0.02	0.06^{ns}	18.24	22.76^{ns}
P12	Gastight silo	65.27	65.06^{ns}	87.32	79.47*	0.13	0.12^{ns}	12.68	19.88**
P13	Gastight silo	65.60	65.67^{ns}	84.66	79.88^{ns}	1.83	2.52*	10.88	15.11**

^{ns} = not significant; * = significant at 5% level; ** = significant at 1% level.

TABLE 6
Percent germination of paddy during field trials

Trial no.	Stack code	Treatment	Initial	Final
II	P4	Gastight	98.67 a	89.33 b
II	P5	Gastight	97.67 a	100.00 a
II	P6	Control	97.67 a	98.33 a
III	P7	Gastight	95.67 a	93.33 b
III	P8	Gastight	88.33 a	86.00 a
III	P9	Control	95.00 a	91.67 a
IV	P10	Gastight	86.00 a	89.33 a
IV	P11	Gastight	83.67 a	83.00 a
V	P12	Gastight silo	93.67 a	93.00 a
VI	P13	Gastight silo	95.33 a	94.77 a

In a row, means followed by the same letter are not significantly different at 5% level using LSD test.

TABLE 7
Percentage weight loss in paddy stacks during the trials

Trial number	Stack code	Treatment	Percent weight loss
II	P4	Gastight	0.32
II	P5	Gastight	0.21
II	**P6**	**Control**	**4.85**
III	P7	Gastight	0.29
III	P8	Gastight	0.27
III	**P9**	**Control**	**3.75**
IV	P10	Gastight	0.19
IV	P11	Gastight	0.10
V	P12	Gastight silo	0.26
VI	P13	Gastight silo	0.13

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