Storage of Bagged Maize Sealed in Plastic Enclosures in the Philippines

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Abstract

This paper reports on trials of the efficacy of a long-term sealed storage technique based on carbon dioxide or phosphine atmospheres as alternative means of controlling pest infestation and related quality losses in large stacks of maize in the Philippines. Fourteen 230 tonne bag-stacks of white maize were observed for storage periods ranging from 61–283 days. Eleven stacks were sealed. Nine of the sealed stacks were treated with carbon dioxide and 2 with phosphine. The other 3 stacks remained unsealed and were surface treated with protectant insecticides to serve as controls reflecting standard storage practice.

Both gases provided satisfactory insect control. In the sealed stacks, significantly lower counts of primary and two secondary insect pests were observed. Insect-damaged grain and weight losses were also reduced. Likewise, there were decreases in mould growth and mould-infected grains as compared with the insecticide-treated control stacks.

The significance of the results, in terms of the reliability and acceptability of the sealed plastic enclosure technique, is discussed.

IN the Philippines, large quantities of maize (corn) are stored. White maize is the second most important staple food, while yellow maize is used as a stock food ingredient.

Large quantities of maize are usually stored in warehouses by private traders/millers and by the government through the National Food Authority (NFA). The grain is commonly packed and handled in 50 kg polypropylene bags, and stored in large stacks for varying periods. Normally, the private sector holds grain for shorter times averaging just over 2 months, while the NFA stores maize for an average of 6 months as buffer stocks to provide food and feed security for the country.

Stored maize has always been subject to problems of pest infestation, especially insect pests, and the problems become greater during long-term storage. In these circumstances, the NFA uses chemical control measures consisting of repeated surface application of grain protectants and fumigation. Nevertheless, the problem remains, as evidenced by the large losses (11% over an 8-month period) incurred (Sabio et al. 1984).

A possible solution to the problem is seen in the sealed plastic enclosure technique for storing of stacks of bagged grain and treating them with carbon dioxide (CO_2) or phosphine (PH_3). This technology, which was initially developed in Australia, has been reported as providing not only initial disinfestation, but also a barrier against reinfestation, thereby offering long-term grain protection (Annis et al. 1984). The technique has been successfully applied in Australia, Indonesia, and Papua New Guinea on rice and coffee (Annis and Graver 1986), but not on maize.

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An assessment of the sealed enclosure storage technique for storage of bagged maize stacks was therefore undertaken, with the primary objective of evaluating and providing information on its technical suitability, economic feasibility, and social acceptability, using CO_2 and phosphine gases as fumigants. Specifically, the study aimed to assess the reliability of the technique in terms of protection from reinfestation by insects and maintenance of maize quality during long-term storage.

Materials and Methods

The field trials were conducted in two private warehouses leased by the NFA in Cebu City, Philippines from November 1985 to June 1988. The warehouses were of concrete construction and roofed with green-painted corrugated iron sheeting interspersed with translucent fibreglass sheeting to provide natural lighting. Heavy infestation by rodents and birds was observed in these warehouses. Heavily insect infested stocks of maize and rice were also present in the warehouse at the time of the study. The test commodity (white maize) was drawn from the stocks procured by NFA in General Santos City and South Cotabato on Mindanao island.

Fourteen 228–249 tonne stacks measuring 11 m long × 7.3 m wide × 4.6 m high were constructed. Eleven of these stacks were sealed, and nine treated with CO_2 and two with phosphine. Details of the stacks used in the five trials are given in Table 1.

The main objective of the early trials was to evaluate the efficacy of the technique using CO_2 in terms of all the parameters set out for this study. The last trial aimed to investigate the efficacy of phosphine as an alternative fumigant to CO_2. Three stacks were left uncovered and used as controls. They were subject to the usual NFA pest control program, which mainly involved stack spraying, fogging, and fumigation with phosphine.

All stacks were built according to the 'Chinese stacking system', except that an aisle was provided to facilitate collection of samples from marked bags at the middle of the stacks. These were constructed 1.5 metres away from the wall and 1 metre apart from each other. The experimental layout of each trial is illustrated in Fig. 1 (a–d).

The stacks used for CO_2 and phosphine treatments were sealed in flexible plastic enclosures, tested for gastightness (Annis and Graver 1986). The top, or cover, sheets were made of nylon fibre reinforced PVC of approximately 350 g/m^2, and the floor sheets of 0.8 mm unsupported PVC sheeting. When the standard pressure test had been achieved, the sealed stacks were fumigated.

The CO_2 was applied in the manner described by Annis and Greve (1984). Liquid CO_2 was obtained from inverted cylinders of compressed gas (food grade quality, nominal capacity 22 kg) which were fastened in a specially devised discharging rack (Fig. 2).

Fumigation of stacks with phosphine-generating tablets was undertaken according to the conventional procedure. The total number of tablets needed for fumigation was appropriately distributed around the stack. Tablets were introduced through slits about 25 cm long, cut along the folded 'skirt' of the covers on all sides (Fig. 3) after pressure testing had been successfully completed. These slits were immediately resealed.

Table 1. History of maize stocks used

Treatment	No. of stacks	Mass (tonne)	Initial condition	Duration of trial (days)
CO_2	9	228–247	3 months old, slightly infested 9 months old, heavily infested	155–239
PH3	2	231–240	1 month old, with few insects alive	136–142
Control	3	228–249	1 month old with few insects alive; 3 months old, lightly infested	135–283

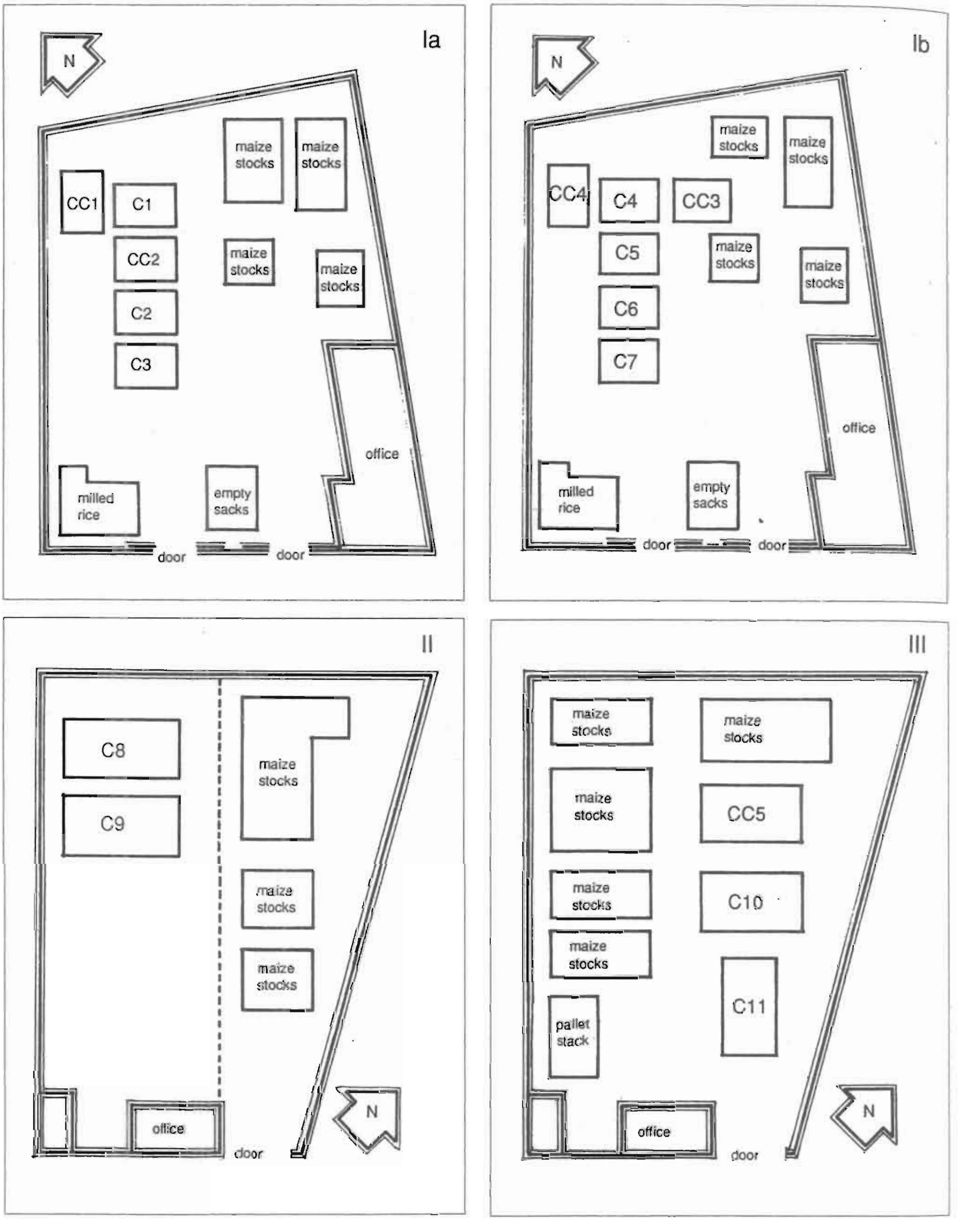

Fig. 1. Configuration of warehouse and stacks for field trials Ia and Ib, II, and III on stored maize. C = treated maize; CC = control stacks.

Details of pressure test results and dosages of CO_2 and phosphine are given in Table 2.

Table 2. Summary of CO_2 and PH_3 dosage rates and gastightness of enclosures

Stack code	CO_2 dosage (kg CO_2/tonne)	Pressure test result
C1	2.08	31 min 15 sec
C2	2.08	35 min 8 sec
C3	1.84	36 min 28 sec
C4	1.83	25 min 37 sec
C5	1.11	25 min 17 sec
C6	1.69	22 min 37 sec
C7	1.61	20 min 5 sec
C8	1.5	10 min
C9	1.5	12 min
	PH_3 dosage	
C10	1 tablet/tonne	5 min
C11	1 tablet/tonne	8 min

Grain sampling was carried out at the start and end of the trial. Composite samples (2 kg), made up from samples speared from all bags in the stack, were gathered. Additionally, 1 kg samples were collected with spears from the 24 individually marked bags.

Moisture content determinations were carried out by drying grain samples for one hour in a vented oven at 130°C (Anon. 1982). Total insect numbers were obtained by counting all adult insects, both live and dead, sieved from the samples. The numbers of insect-damaged grain kernels needed for estimation of weight loss were determined by hand counting the number of damaged kernels in a 1000-grain sample. The magnitude of losses incurred was assessed through the count and weigh method (Harris and Lindblad 1979). The insect species responsible for damaging the grains were classified as primary pests and others as secondary pests for the purpose of this study.

The presence of fungi on grains and the extent of microbial infection were determined by plating sterilised grains in potato dextrose agar.

Gas concentrations were monitored by drawing samples out of the stacks through semi-rigid nylon gas sampling lines (2 mm i.d.) and Draeger detector tubes with a Draeger pump (Fig. 4).

Assessment has also been made of the operational convenience and cost of keeping bagged maize stacks in sealed plastic enclosures under CO_2 and phosphine atmospheres (Annis 1990).

Results

Percentage Moisture Content

The moisture content of maize in stacks sealed for an average period of 4.6–7.8 months did not significantly change, whereas in the

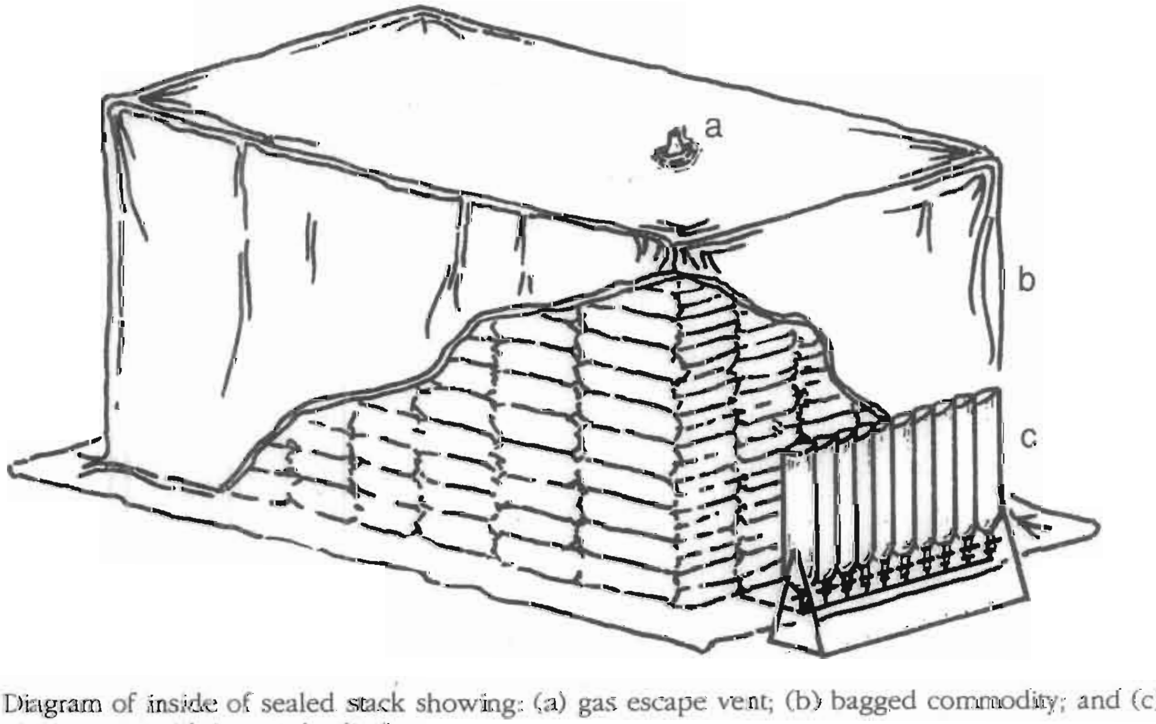

Fig. 2. Diagram of inside of sealed stack showing: (a) gas escape vent; (b) bagged commodity; and (c) CO_2 introduction system with inverted cylinders.

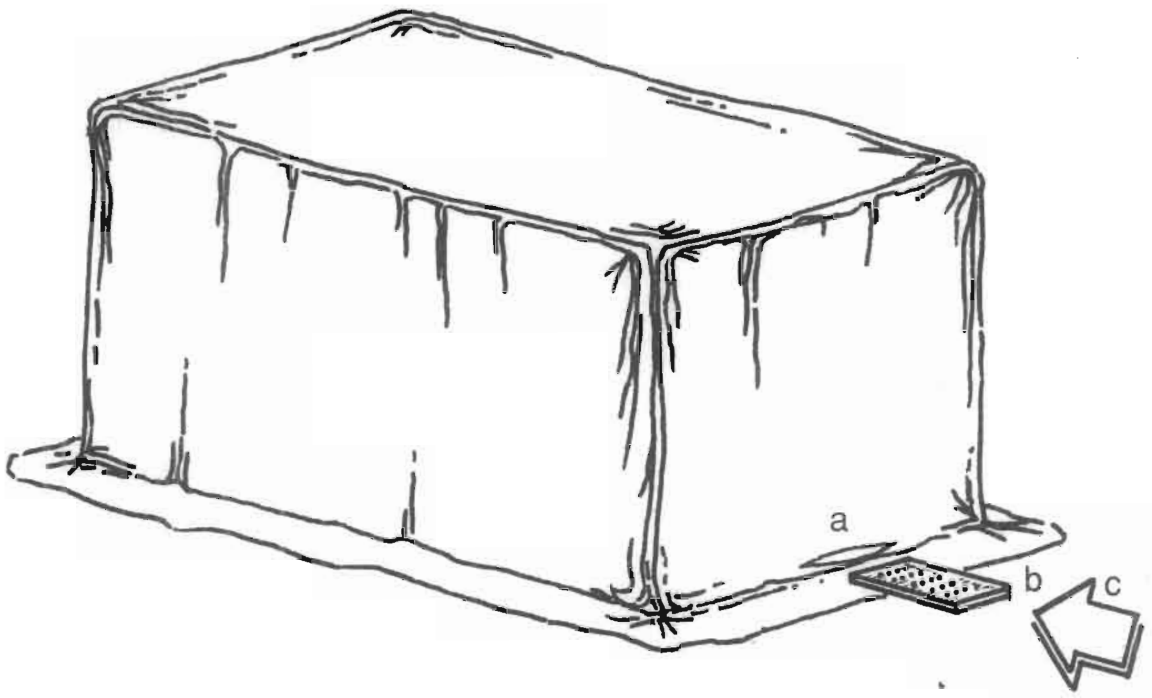

Fig. 3. Diagram of enclosed stack showing: (a) open slit on the lateral 'skirt' of cover sheet; (b) PH_3 tablets in a corrugated cardboard box; and (c) entry direction.

control stacks the moisture content in one stack fell by 1.6% after 4.5 months and by 0.7–1.0% in the other two after 9.3 months of storage. Other sealed stacks stored for a year or more have shown a significant decrease in moisture content ranging between 0.4 and 1.3%. (A very low moisture content of 10.2% has been recorded in two stacks after 13 months storage.)

Insect Infestation

Initial and final counts of the primary pests,

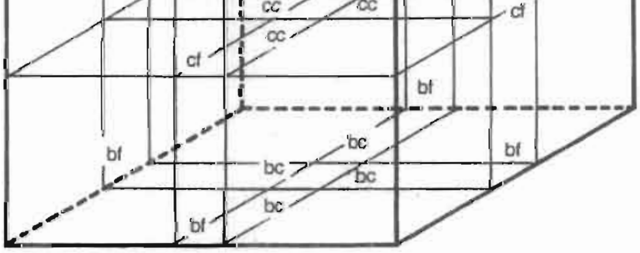

Fig. 4. Predetermined sampling points (24) within the stacks: tf = top face; tc = top core; cf = centre face; cc = centre core; bf = bottom face; bc = bottom core.

Rhyzopertha dominica and *Sitophilus zeamais* and of the secondary pests *Cryptolestes* spp. and *Tribolium castaneum* revealed no significant increases in most sealed stacks (Tables 3-4). However, in the control stacks large increases in the number of these pests were observed (Table 5).

Percentage Insect-Damaged Grain

The percentage of insect-damaged grain did not significantly change (Table 6) in the two phosphine-treated stacks and in most of the seven CO_2 treated stacks after 4.6 and 7.8 months of storage, respectively. On the other hand, in the control stacks for both trials there were significant levels of damaged kernels, reaching 1.9% over 4.5 months storage and 2.5–5.7% over 9.3 months.

Percentage Weight Loss

No significant increases (Table 7) in percentage weight loss were observed in the phosphine-treated stacks after 4.6 months of storage, while in the control a 6.6% increase was observed. In the CO_2-treated stacks, there was no significant change in two stacks but a significant increase was recorded in one stack at the end of 7.8 months. The magnitude of loss observed did not significantly differ from that recorded in the two control stacks observed.

Table 3. Increase in density of major insect pests in CO_2 treated stacks.

Stack code	Insect species *Rhyzopertha dominica*	*Sitophilus zeamais*	*Tribolium castaneum*	*Cryptolestes* spp.	No. of observations
C2	NS (0)	*** (0,3)	*** (1,15)	*** (1,13)	48
C3	NS (1)	NS (0)	*** (2,14)	*** (2,15)	48
C6	NS (1)	NS (1)	NS (1)	NS (33)	48
C7	NS (1)	NS (4)	NS (2)	NS (7)	48
C8	NS (1)	NS (3)	NS (3)	NS (2)	48
C9	NS (0)	NS (0)	NS (0)	NS (2)	48

NS P > 0.050; initial count in brackets (insects/kg)
* P < 0.050
** P < 0.025 initial and final counts in brackets (insects/kg)
*** P < 0.010

Table 4. Increase in density of major insect pests in phosphine-treated stacks

Stack code	Insect species *Rhyzopertha dominica*	*Sitophilus zeamais*	*Tribolium castaneum*	*Cryptolestes* spp.	No. of observations
C10	** (2,3)	NS (5)	*** (3,5)	NS (3)	54
C11	NS (2)	NS (6)	NS (5)	NS (10)	54

NS P > 0.050; initial count in brackets (insects/kg)
* P < 0.050
** P < 0.025 initial and final counts in brackets (insects/kg)
*** P < 0.010

Table 5. Increase in density of major insect pests in control stacks

Stack code	Insect species *Rhyzopertha dominica*	*Sitophilus zeamais*	*Tribolium castaneum*	*Cryptolestes* spp.	No. of observations
CC1	*** (0,71)	*** (0,17)	*** (0,48)	*** (2,46)	48
CC2	*** (0,18)	*** (0,5)	*** (1,34)	*** (0,46)	48
CC3	*** (2,8)	** (4,8)	*** (5,15)	NS (9)	54

NS P > 0.050; initial count in brackets (insects/kg)
* P < 0.050
** P < 0.025 initial and final counts in brackets (insects/kg)
*** P < 0.010

Microbial Infection

Stacks of newly procured maize were initially found to heavily infected with *Aspergillus flavus* (93–100%) and *A. niger* (27–93%). Infections with *Penicillium* sp., *Rhizopus* sp., and *Diplodia* sp. were also noted but at a much lower level. Other stacks of older and drier grains were found to be infected with all these fungal species except *Diplodia* sp., but to a lesser extent overall. Final results (Table 8) indicate that infection with *A. flavus* in sealed stacks of newly procured grains fell by 55–57% to after 4.6 months storage and 83–90% after 7.8 months. Infection with *A. niger* fell to zero after 4.6 months and by 85–100% after 7.8 months. The percentage of infected grains in sealed stacks of older grains fell slightly. Levels of infection by *Penicllium* in control stacks increased 4.5 times after 4.6 months storage, but decreased by 38.9% and 9.5% for *A. flavus* and *A. niger*, respectively.

Discussion

To show that a proposed pest control method is reliable and acceptable it is necessary to demonstrate:

- that it will kill all the target pests;
- that it will not harm the commodity; and

- that it can be carried out within the resources (human and material) available.

The observations reported in this paper address two of these requirements: insect control and damage to the commodity.

If a disinfestation is not complete in a sealed insect-infested commodity there are two likely consequences: as insect damage increases dry matter loss rises and the metabolic activity of the insects may cause heating. This, in turn, will lead to moisture migration, with the attendant possibility of moulding.

On the simple basis of numbers of live insects, all treatments in the trials reported were successful, there never being more than a few live insects at the end of the storage period no matter how long it was. There was, however, occasionally a significant increase in the number of dead insects during the storage period, suggesting that population death had taken some time to occur or, as is more likely, that the more tolerant and less obvious immature stages continued to develop to the less tolerant and more obvious adults before dying. Neither of these possibilities is excluded by the observations of percent insect-damaged grains which showed increases in damage in three of the six CO_2-treated stacks. This was matched by a corresponding percentage weight loss in only one stack, suggesting the damage was caused by emerging rather than feeding insects.

In the control stacks there was virtually always a significant increase in numbers of insects, many of which were alive at the end of the storage period.

There was no significant moisture build up or localisation in either the treatments or in the controls. There was moisture loss from the control stacks and there appeared to be a moisture reduction in the sealed stacks stored for a year or more. There was no increase in percent of kernels infested with storage fungi in the tests, an observation consistent with the grain moisture observations. Phosphine treatments appeared to give rise to a significant reduction in the three fungi isolated, as also did CO_2, but to a lesser extent. These findings were unexpected and, while promising, will need investigating under more carefully controlled conditions before any reliance can be placed on them.

Table 8. Percentage reduction of infected kernels with major storage fungi

Species	Treatments			
	CO_2		PH_3	Control
	New grain	Old grain	New grain	New Grain
Aspergillus flavus	86.8%	25.2%	56.2%	38.9%
A. niger	92.8%	23.3%	100.0%	9.5%
Penicillium sp.	–	26.0%	100.0%	increased (4.5×)

Table 6. Number of stacks showing different levels of significance of increase in percentage insect damaged kernels

Treatments	Levels of significance				
	NS	0.05–0.025	0.025–0.01	0.01–0.005	<0.005
CO_2	3	1	1	1	1
PH_3	2	–	–	–	–
Control	–	–	–	–	3

Table 7. Number of stacks showing different levels of significance of increase in percentage weight loss

Treatments	Levels of significance				
	NS	0.05–0.025	0.025–0.01	0.01–0.005	<0.005
CO_2	0	–	1	–	–
PH_3	2	–	–	–	–
Control	–	1	–	–	1

Conclusion

Safe long-term storage of dry bag-stacked maize is possible in sealed plastic enclosures. If disinfestation is complete then there appears to be a significant advantage to this kind of storage. The initial disinfestation can be carried out using either phosphine or carbon dioxide. Whichever treatment is used, there is some reduction in the number of insect-damaged kernels and a significant reduction in percentage weight loss.

Acknowledgments

These field trials were carried out by NAPHIRE with the support of ACIAR. The National Food Authority of the Philippines provided the test commodity, warehouse facilities, and other logistic support.

The authors acknowledge the expert technical guidance of Mr Peter Annis and Mr Jan van Graver from the CSIRO Division of Entomology, Canberra, Australia, and the expert technical assistance of Mr Joel Dator and Miss Lorna Caputol from NAPHIRE, CLSU Compound, Nueva Ecija, Philippines.

Thanks are also due to the NFA officials and staff in Cebu City, Philippines for their invaluable support and co-operation towards the successful implementation of this study.

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