Modified atmosphere storage of bagged maize outdoors using flexible liners: a preliminary report

D.G. Alvindia, F.M. Caliboso, G.C. Sabio and A.R. Regpala*

Abstract

Field trials were carried out in the Philippines for outdoor storage of maize sealed in flexible liners. Two storage atmospheres were evaluated: carbon dioxide (CO_2)-enriched and hermetic storage.

Tests were carried out to determine insect infestation, moisture content, microbial infection, weight loss, grain quality and seed germination.

Insect infestation was completely prevented in the CO_2-enriched cubes while few live insects were noted in the hermetic cubes. Insect-damaged kernels and weight loss were minimised. Grain moisture content remained stable after three months although mould growth was noted at the top surface of the stacks. Grain quality was preserved and seed germination was not affected.

Introduction

In the Philippines, few farmers and cooperatives store their grains in well-designed, purpose-built structures. Those without storage facilities usually stack bagged grain in barns, under the eaves of their residences and in the open. Depending on climatic conditions, such stacks are covered with tarpaulins, or plastic sheets. Typically, these storage sites lead to losses caused by insect infestation, moulding, rodents and birds. Another option for the farmers is to sell their produce immediately after harvest. However, the price of grains is depressed during harvest and safe temporary storage is necessary until the market price is more favourable.

Advances in storage technology has led to the development of flexible PVC liners to envelope stacks of bagged grains for outdoor storage (Donahaye and Navarro 1989). The development of 'storage cubes' was designed for the hermetic storage of grains in situations where permanent structures are not available (Donahaye et al. 1991). It is also designed for the application of modified atmospheres to prevent reinfestation of the commodity during prolonged storage.

Field evaluation of storage 'cubes' under carbon dioxide (CO_2)-enriched and hermetic conditions have been conducted to determine its applicability under Philippine conditions.

Materials and Methods

Site and duration of storage

Storage trials were conducted at Farmers' Cooperative Incorporated (FCI), Kisolon Sumilao, Bukidnon from 28 October 1991 to 31 January 1992 and 2 April 1992 to 8 July 1992. Details of the trials are given in Table 1.

* Food Protection Department, National Post Harvest Institute for Research and Extension, CLSU Compound 3120, Nueva Ecija, Philippines.

Grain supplies

Newly-harvested locally-grown yellow maize bagged in 50 kg polypropylene sacks was provided by the Farmers Cooperative Incorporated. Maize was dried down below 14% m.c. using a mechanical drier.

Storage structures

The storage cubes were manufactured by Haogenplast Ltd, Israel. These consisted of a lower floor–wall section and an upper roof–wall section. The lower floor–wall section was made of white flexible 0.83-mm-thick polyvinyl chloride (PVC) sheeting while the top cover was made of white nylon reinforced chlorinated polyethylene (CPE) plastic sheet which provided protection from degradation by UV radiation (Donahaye, pers. comm.). The storage cubes are equipped with ports to allow application of modified atmospheres or conventional fumigants by gravity displacement (Donahaye and Navarro 1989). The lower floor–wall and the upper roof–wall are sealed together by a gas-proof zipper. The zippers are covered by a protective over-flap. Dimensions of the 20-t 'cubes' are 4450 × 3360 × 2000 mm (length × width × height) with a maximum storage volume of 29.9 m^3, and a weight of 76 kg when empty. Provision was made, by means of tension straps and buckles attached to the liner, to keep the walls of the cubes under tension even when they are not filled to capacity. This ensures that there are no folds of material at point of contact around the floor level, thus affording a large measure of protection from rodent penetrations (Navarro and Donahaye 1986).

The control maize was stacked on the wooden pallets and covered with tarpaulin plastic sheets.

Loading

Stacks were set up on a selected area which was cleared of sharp objects. Stacks were built directly on the lower floor-–wall section which were spread out straight on the ground. Loading was manually done with 35 bags (5 × 7) per layer and nine layers to a height of 1.9 m. Stacks were constructed in a pyramid shape to allow rain water to run-off immediately on the sides of the cubes.

Grain sampling

Samples were collected during loading and immediately after the trial. Three composite samples of 1 kg were collected from all bags in the stacks using sampling spears. An additional 500 g was collected from the 15 individually marked bags.

Instrumentation

T-type thermocouple cables and 3-mm-diameter plastic tubings were installed at different locations inside the cubes to monitor temperatures and gas composition during storage (Fig. 1).

Table 1. Details of storage trials.

Trial no.	Stack code	Treatment	Volume (t)	Duration (days)
I	C1	CO_2-treated	18.45	93
	C2	Hermetic	15.02	93
	C3	Control	4.75	93
II	C4	Hermetic	17.00	97
	C5	CO_2-treated	16.62	97
	C6	Control	4.58	97

Insulation

The top surface of each stack was insulated by adding one layer of dry bagged maize cobs. This was designed to prevent or reduce heat-flow and temperature fluctuations in grains.

Gassing

Food grade CO_2 at the rate of 1.5 kg/t was used to establish the modified atmosphere. The gas applicator was made of a flexible metal tube attached to the gas tank valve that was fixed onto the inlet valve of the cube.

Parameters

Moisture content determinations were carried out by drying grain samples for one hour in the oven (Anon. 1982). Live insects were sieved from the composite and representative samples. These were sorted according to group and species.

The extent of fungal infection was determined by plating 30 seeds randomly taken from composite samples into each media of Aspergillus Flavus Parasiticus Agar (Pitt et al. 1983); Diglycerol Glucose Agar (Hocking and Pitt 1980), Dichloran Rose Bengal Chloramphenicol Agar (King et al. 1979) and Dichloran Chloramphenicol Agar (Nash and Snyder 1962).

Temperature was recorded daily between 0800–0900 hours; 1200–1300 hours and 1600–1700 hours using the Anritsu type-T model HL600. CO_2 levels were monitored right after gassing and after 1,3, 5, 9, 11 and 15 days. Thereafter, weekly monitoring was done. The CO_2 level in the hermetic cubes was monitored weekly.

Quality evaluation was carried out to determine the effect of modified and hermetic atmosphere storage on maize. The calculation of quality parameters was determined by hand counting the number of insect damaged, discoloured, mouldy and germinated kernels in each 500 g grain sample. Viability was estimated using the rag-doll method. The actual weight loss was calculated from the difference between the weight of bagged maize at the start and at the end of the storage trial.

Data were statistically analysed using the Multi-Factor Analysis of Variance (AVMF).

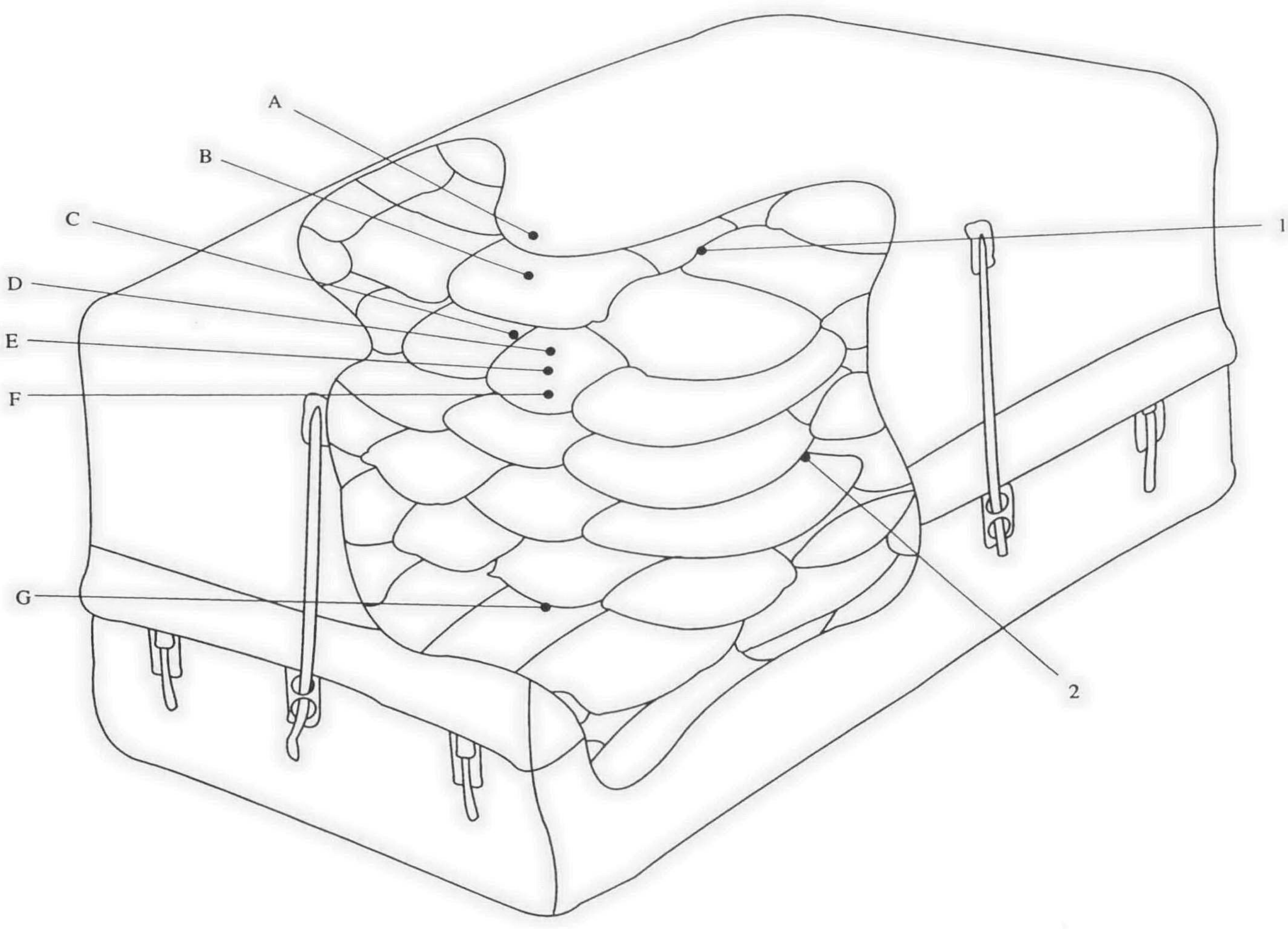

Fig. 1. Diagram of experimental stack, showing the different temperature and gas-sampling points. Tempereature sensors are located at: (A) above liner; (B) below liner; (C) below insulation; (D) 5 cm inside uppermost bag; (E) 10 cm in; (F) 20 cm in; (G) core of the stack. Gas concentration tubings are located at: (1) below liner; (2) middle core.

Results

Percentage moisture content

The moisture content of maize in both treatments and controls did not significantly change over the treatment period of 95–97 days (Table 2).

Table 2. Moisture content of maize at start and end of treatments with modified atmospheres in sealed flexible storage cubes.

Stack code	Treatment	Initial	Final	Difference
C1	CO_2-treated	13.16	12.16	ns
C2	Hermetic	12.56	12.56	ns
C4	CO_2-treated	11.59	11.93	ns
C5	Hermetic	11.44	11.72	ns
C3	Control	13.26	12.23	ns
C6	Control	11.98	11.82	ns

ns $P > 0.050$

Insect infestation

Initial and final counts of live insects did not significantly change in CO_2-enriched and hermetic stacks. However, the number of live insects increased significantly over time in the control stacks (Table 3).

The number of live infestations recorded in the hermetic stacks were: *Sitophilus zeamais* (1), *Tribolium castaneum* (1) in the first trial and *Rhyzopertha dominica* (1) in the second trial. The live infestations recorded in the control stacks include all the major pests of maize in storage (*Sitophilus zeamais, Rhyzopertha dominica, Tribolium castaneum, Carpophilus hemipterus* and *Latheticus oryzea*).

Microbial infection

The various species of fungi isolated from maize and their extent of infection before and after the trial is summarised in Table 4. Stacks of newly-harvested maize were initially infected with *Aspergillus flavus*, other *Aspergillus* species (*fumigatus* and *nidulans*), *Eurotium chevalieri, Penicillium citrinum* and *Fusarium moniliforme.*

Results indicate that infection with *Aspergillus flavus* in the CO_2-treated and hermetic stacks of newly harvested maize fell by 100% and 70%, respectively after 3 months of storage. Levels of infection by other *Aspergillus* species in maize increased 14 times in the CO2-treated stacks and 4 times in the hermetic stacks. Likewise, infection by *Fusarium moniliforme* increased to 7.5 and 30 times in the CO_2-enriched and hermetic stacks, respectively. Level of infection by various fungi in the control stacks generally increased after storage.

Table 3. Average insect density in 1 kg samples of maize before and after storage.

Treatment	Trial I		Trial II	
	Initial	Final	Initial	Final
CO_2-treated	0 a	0 a	0 a	0 a
Hermetic	0 a	0.67 a	0 a	0.33 a
Control	1.71 a	68.66 b	0.30 a	17.33 b

Means followed by the same letter are not significantly different at 5% level of significance.

Storage and ambient temperatures

Temperatures recorded inside the CO_2-treated and hermetic stacks (Figs 2 and 3) were generally lower when compared to the ambient. Point a, which measured the temperature above liner showed greater fluctuations due to differences in time of day and weather conditions. In spite of the temperature fluctuations outside the storage cubes, temperature inside the cubes remained stable whereas in the control stacks, wide temperature fluctuations were recorded (Fig. 4).

Carbon dioxide levels

The CO_2 level of more than 35% was maintained for 11 weeks in the modified atmosphere cube (C1) while highest CO_2 level recorded in the hermetic maize stacks (C2) was 7% (Fig. 5).

Grain quality

The quality of maize under CO_2-enriched atmospheres did not significantly change after 3 months of storage. A significant increase in discoloured and insect-damaged kernels were noted on the hermetic stack C4. But other quality parameters where not significantly changed. Discoloured and insect-damaged grains in the control stacks significantly increased over the storage period.

Maize germination

Germination of maize did not significantly change during storage irrespective of storage technique employed.

Weight loss

The extent of percentage weight loss in maize stored under CO_2-enriched atmosphere (0.252–0.265%) and hermetic condition (0.229–0.379%) was lower than conventionally stored maize (5.073–5.611%) (Table 5).

Table 4. Percentage fungal infection in maize stacks at various storage atmospheres during Trial I and II.

Fungal species	CO_2-treated		Hermetic		Control	
	Initial	Final	Initial	Final	Initial	Final
Aspergillus flavus	23	0	23	7	11	7
Other *Aspergillus* spp.	0	14	0	4	4	7
E. chevalieri	40	1	2	11	2	39
P. citrinum	2	0	0	0	2	6
F. moniliforme	2	15	1	30	2	28

Table 5. Change in actual weight in maize stored under various conditions

Stack code	Treatment	Initial weight	Final weight	Variance (kg)	% weight loss
C 1	CO_2-treated	18450	18401	49	0.265
C2	Hermetic	15020	14963	57	0.379
C4	Hermetic	17000	16961	39	0.229
C5	CO_2-treated	16620	16578	42	0.252
C3	Control	4750	4509	241	5.073
C6	Control	4580	4323	257	5.611

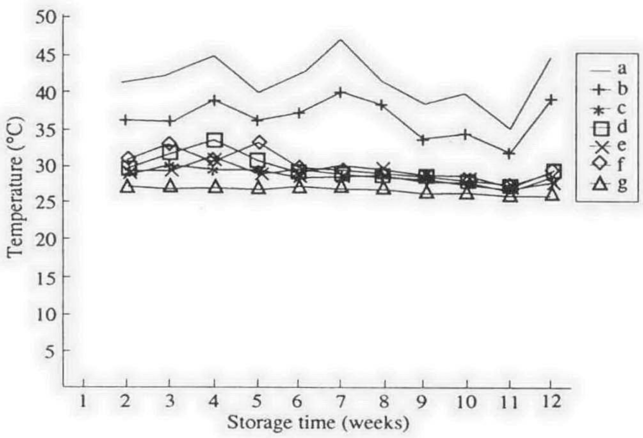

Fig. 2. Temperature recorded from seven different points in the CO_2-treated maize (Stack 5); a, above the liner; b, above insulation; c, below insulation; d, e, f, 5, 10, 20 cm in from the top surface of the same bag; g, core of the stack.

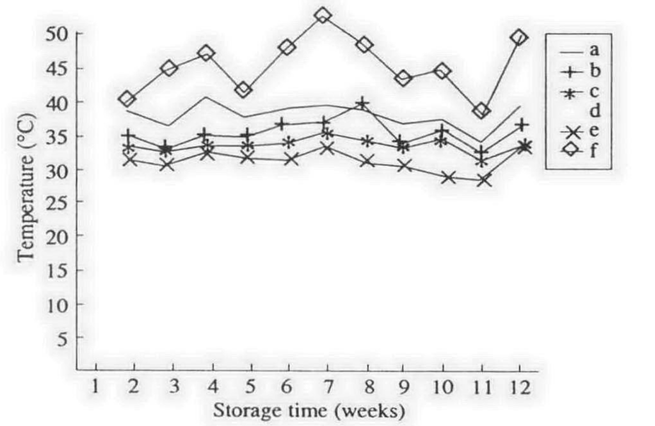

Fig. 4. Temperature recorded from six different points in the control maize (Stack 6); a, above the liner; b, top surface of the centre bag at the uppermost layer of the stack; c, d, e, 5, 10, 20 cm in from the top surface of the same bag; f, core of the stack.

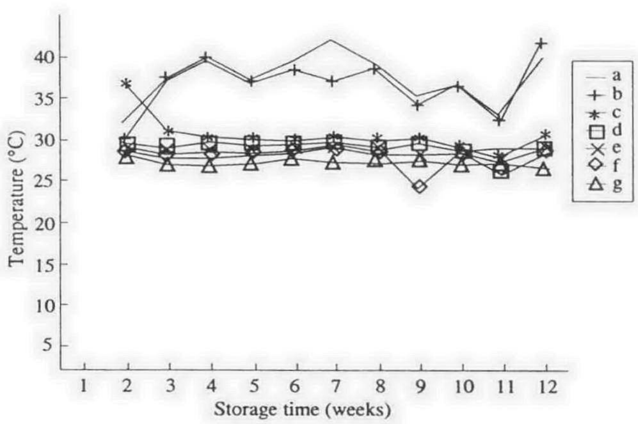

Fig. 3. Temperature recorded from seven different points in the hermetically stored maize (Stack 4); a above the liner; b, above insulation; c, below insulation; d, e, f, 5, 10, 20 cm in from the top surface of the same bag; g, core of the stack.

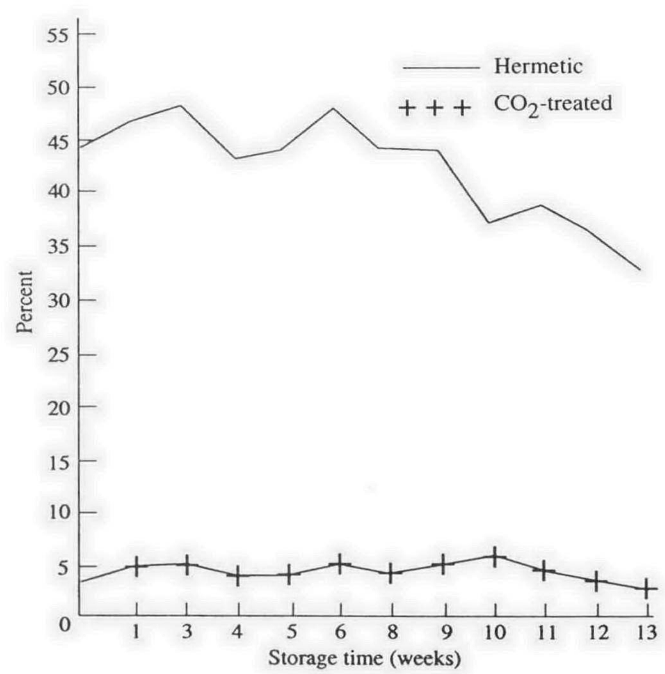

Fig. 5. Carbon dioxide concentrations recorded in CO_2-treated and hermetic maize stacks.

Discussion

The results provided information on the use of PVC flexible liners for modified atmosphere storage of maize in the Philippines. They also demonstrated the insect control capacity of the technology as part of a quality preservation system.

The standard assessment that there should be no live insects after storage was attained in the CO_2-enriched stacks. The complete disinfestation of stacks in the CO_2-enriched cubes demonstrated the enclosures gastightness, to hold the required standard and gas concentrations of 35% for at least 10 days (Annis et al. 1984). In the hermetic cubes, light infestation was evident (0.33–0.67 live insects/kg) after storage. Despite the presence of live insects, no significant increase of insect damaged kernels was noted.

Mould growth was visible in the CO_2-enriched and hermetic storage cubes. Mould growth in the CO_2-enriched cubes was limited to the insulation while mould growth on the hermetic cubes was noted on the insulation and on the bags immediately underneath. Moulding was attributed to the inadequate drying of insulation.

There was no significant increase in the moisture content of maize stored under modified and hermetic atmospheres. Weight loss in the modified atmosphere cubes was calculated at 0.25 and 0.30% in the hermetic stacks. These values should be compared with loss evaluation of 5.34% in the conventional storage.

The quality of maize was not significantly affected by modified atmosphere storage. It appears that storage of maize under CO_2-enriched and hermetic atmospheres is better than the conventional practice. However, further work is required under more tightly controlled conditions to quantify the effect of modified atmosphere on maize quality.

The effect of modified atmospheres on maize germination suggest that it can be used for seed storage purposes. The result corroborates the findings of Bason et al. (1987) and Gras and Bason (1989) that carbon dioxide levels of 7.5 to 60% had no significant effect on the mean life-span retention period of maize.

Conclusion

Storage of maize for three months in cubes under CO_2-enriched atmospheres prevented insect infestation. Meanwhile, few live insects were recorded in the hermetic cubes. Both storage systems appeared to have advantage in minimise insect-damaged kernels and weight loss.

Modified atmosphere storage of maize under plastic enclosures provides significant advantages of maintaining quality and germinability of maize. The effect of modified atmospheres under plastic enclosures outdoors on the grain microflora would require further research before any conclusion can be drawn.

Acknowledgments

These field trials were carried out with the support of Agricultural Research Organization, Israel. The Farmers' Cooperative Incorporated, Kisolon, Bukidnon provided the test commodity and other logistic support.

Thanks are also due to the National Food Authority of the Philippines officials and staff of Cagayan de Oro City and Malaybalay, Bukidnon for their support and cooperation during the implementation of the field trials.

References

Annis, P.C., Banks, H.J. and Sukardi 1984. Insect control in stacks of bagged rice using carbon dioxide treatment and an experimental PVC-membrane enclosure. CSIRO Australia Division of Entomology Technical Paper No. 22.

Anon. 1982. Approved methods of the American Association of Cereal Chemists, revised ed. St. Paul, Minnesota, American Association of Cereal Chemists.

Donahaye, E. and Navarro, S. 1989. Flexible PVC liners for hermetic or modified atmosphere storage of stacked commodities. In: Champ, B.R., Highley, E. and Banks, H.J., ed., Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 271.

Donahaye, E., Navarro, S., Ziv, A., Blauschild, Y. and Wirrasinghe, D. 1991. Storage of paddy in hermetically sealed plastic liners in Sri Lanka. Tropical Science, 31, 109121.

Gras, P.W. and Bason, M.L. 1989. Biochemical effects of storage atmospheres on grain and grain quality. In: Champ, B.R., Highley, E. and Banks, H.J., ed., Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 83–91.

Hocking, A.D. and Pitt, J.I. 1980. Dichloran–glycerol medium for enumeration of xerophilic fungi from low moisture foods. Applied and Environmental Biology, 39, 488–492.

Navarro, S. and Donahaye, E. 1986. Plastic structures from temporary storage of grain. In: Semple, R.L. and Frio, A.S., ed., Research and development systems and linkages for a viable grain post-harvest industry in the tropics. Proceedings of the 8th ASEAN Technical Seminar on Grain Post-harvest Technology, Manila, Philippines, 189–194.

King, A.D., Hocking, A.D. and Pitt, J.I. 1979. Dichloran–rose bengal medium for enumeration and isolation of moulds from foods. Applied and Environmental Biology, 37, 959–964.

Nash, S.M. and Snyder, W.C. 1962. Quantitative estimations by plate counts of propagules of the bean rot, *Fusarium* in field soils. Phytopathology, 52, 567–572.

Pitt, J.I., Hocking, A.D. and Glenn, D.R. 1983. An improved medium for the detection of *Aspergillus flavus* and *Aspegillus parasiticus*. Journal of Applied Bacteriology, 54, 109–114.