PHOSPHINE FUMIGATION OF TOBACCO IN FREIGHT CONTAINERS

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Abstract

A series of trials was carried out in Malawi to assess the feasibility of fumigating tobacco, in freight containers, while in transit by rail to ports in neighbouring Mozambique. In containers that were soundly constructed and in an adequate state of repair, it was found that effective fumigations could be undertaken without hazard to operators or to the public at large. Lining the containers with polyethylene film improved gas retention in containers of average to good condition but not sufficiently to produce an effective fumigation in containers that were in poor condition.

Résumé

Une série d'essais a été exécutée à Malawi pour évaluer la possibilité de fumigation du tabac dans des containers pendant son transport par voie ferrée vers les ports du pays voisin, le Mozambique. Dans des containers qui étaient bien construits et en bon état, on a constaté que des fumigations efficaces pouvaient être réalisées sans danger pour les agents phytosanitaires ou pour le public en général. Le recouvrement de l'intérieur des containers avec du polyéthylène a amélioré la rétention du gaz dans les containers dont l'état était moyen ou bon, mais pas suffisamment pour produire une fumigation efficace dans les containers qui étaient en mauvais état.

Resumen

Fue llevada a cabo una serie de ensayos en Malawi con el fin de evaluar la posibilidad de realizar la fumicación de tabaco, en contenedores de transporte, mientras se hallaban en tránsito por ferrocarril hacia puertos en el vecino Mozambique. En aquellos contenedores de construcción sólida y en un estado adecuado de reparación, se descubrió que podían llevarse a cabo fumigaciones eficaces sin que se presentara peligro para los operadores o para el público en general. El forrado de los contenedores con polietileno mejoró la retención del gas en aquellos contenedores cuyas condiciones variaban de medianas a buenas, pero no fue la suficiente para producir una fumigación efectiva en aquellos contenedores en mal estado.

Introduction

A series of trials with freight containers loaded with tobacco was conducted in Malawi, to study variations in phosphine fumigant gas concentrations in them while both static and in transit by rail. Tobacco is an important export commodity, particularly subject to infestation by *Lasioderma serricorne* and some other insect pests, and must be disinfested by fumigation prior to export. The normal procedure for exporting tobacco from land-locked Malawi is that, 12 days prior to loading onto a container vessel at a port in neighbouring Mozambique, empty containers are delivered by road to a tobacco warehouse. After filling they are then taken back to a container terminal from where they go by rail to the port, a minimum journey of five days. The time between loading a freight container with tobacco and stowage on a vessel is often in excess of twelve days.It is therefore possible to carry out fumigation in the containers, but problems could arise due to inadequate gas-tightness which may cause fumigation failure. Moreover, residual concentrations of phosphine in containers, when loaded onto ships, could cause hazards if they were to leak into the ship's holds.

The objectives of the trials were, firstly, to determine whether the type of container used for tobacco was suitable for fumigation and, secondly, to investigate the concentrations of phosphine gas achieved during fumigation and also those remaining in a freight container after a period of time equivalent to that which is normal for the railment of tobacco. For simplicity, transportation tests were carried out within Malawi, but the freight containers were railed

over distances and times equivalent to the minimum likely when they were transported to a port in Mozambique. The results of measurements taken over the extended periods were used to assess the possible hazards, if any, from freight containers being carried on a ship without prior aeration.

Tobacco is a difficult commodity to fumigate since the gas is required to penetrate into tightly packed leaves in hessian bales, cardboard cartons or wooden cases lined with kraft paper or polyethylene film. Consequently tobacco fumigations are normally carried out under carefully controlled conditions either in a special chamber or using very good quality fumigation sheets. Thus it was of importance to establish whether freight containers afforded a sufficiently gas-tight alternative. Phosphine is the preferred fumigant since, in contrast to methyl bromide, it is very easy to apply, does not require expensive application equipment, has very good penetrative powers and causes no residue problems. Furthermore phosphine remains toxic to insects at low concentrations provided that the insects are exposed to these concentrations for an adequate period of time. However, there is little published information on the performance of phosphine in freight containers under operational conditons (Childs, 1971).

Experimental procedure

The 19 freight containers used for the trials were approximately 34 m^3 in capacity and had been used for the delivery of goods to Malawi.

They were standard containers comprising a rectangular metal box with a wooden plank floor and a double door at one end fitted with rubber gaskets with a clamping arrangement to ensure a tight closure. It has been reported that containers in good structural condition afford satisfactory chambers for fumigation provided any ventilators are also sealed, (Freeman, 1968). However, many of the containers inspected at the terminal and several delivered for the trials were unsuitable for fumigation because of damage sustained over several years of previous use. The results of fumigations within defective containers are important for comparative purposes, so it was decided to use all the containers allocated for the trials, after noting any visible signs of obvious damage and leakage points. However, the results from the containers which should have been rejected were excluded from the overall assessment of the likely effectiveness of properly supervised in-container fumigation.

"Phostoxin" tablets were used to fumigate 18 of the containers, while a newer formulation consisting of magnesium phosphide plates, protected before use within a pouch of aluminium foil, was used for one container. The containers were loaded with cartons, cases or bales of tobacco as indicated in Table 1. This table also gives the type and condition of the container used, together with data on treatment and concentration time products of phosphine achieved during the trial.

Preparation of containers used in the trial. Prior to loading, gas sampling lines (nylon capillary tubing of 2mm internal diameter) were fitted to the inside of the door and the end of the container facing the door. Stainless steel gas-sampling spears were also inserted to the centre of selected cartons, boxes or bales of tobacco and connected to lengths of nylon capillary tubing. All gas-sampling capillaries were fed out at the door of the container under the rubber gasket.

In an attempt to improve gas-tightness in those containers (numbers 11-16 in Table 1) which were found, on inspection before loading, to be damaged, lengths of 125 micron polyethylene film were laid over the floor and wall/floor junction allowing 20cm of overlap of adjoining lengths and up the walls. To protect the polyethylene film itself against damage during loading a layer of cardboard was laid over the film. Each container was loaded with approximately 8 tonnes of tobacco in cartons, cases or bales so that only a very small headspace remained unfilled. The temperature of the tobacco during loading was between 19 and 20°C.

Application of fumigant and transport of containers. Fumigant was applied to the containers at the container terminal using 30 tablets of phostoxin (generating 30g of phosphine) per container or, in container number 15, one plate of magnesium phosphide (generating 34g of phosphine).

Containers 1-4 were retained at the terminal while the remainder were loaded onto wagons, connected to a train, and railed around Malawi for the required distance and number of days. Containers 5-10 were railed for a total of 4 days and containers 11-19 spent a total of 5 days on rail. Gas concentration measurements were taken each day or night when the wagons were stationary. After they returned to the container terminal the measurements were continued for at least 12 days.

Table 1 Gas concentrations and CT products at 200 hrs

	Container type	Container* Condition	Tobacco + Load	Formulation Tablets	Formulation Plates	Trial	CT product (mgh/ℓ) Free Space 200 hrs	CT product (mgh/ℓ) Within load 200 hrs Φ	Phospine concentration at Centre of Load after 200 hrs (mg/ℓ)
1.	TOLU	good	Bales	30		Static I	65	67	0.07
2.	CTU	poor	Bales	30			27	36	0.07
3.	DAYU	good	cases	30		"	134	125	0.44
4.	CATU	good	cartons	30		"	124	79	0.19
5.	MMLU	average	cartons	30		In transit II	40	42	0.11
6.	MMLU	good	cases	30		"	44	58	0.18
7.	CTU	good	cartons	30		"	27	36	0.07
8.	TOLU	good	bales	30		"	65	67	0.07
9.	MMLU	poor	cases	30		"	18	24	0.10
10.	UFCU	poor	cases	30		"	25	20	0.08
11.	MMLU	good ϕ	cartons	30		In transit III	106	120	0.25
12.	MMLU	good ϕ	cartons	30		"	50	55	0.16
13.	MMLU	average ϕ	cartons	30		"	60	70	0.14
14.	MMLU	average ϕ	cartons	30		"	53	60	0.14
15.	MMLU	poor ϕ	cartons		1	"	13	—	0.02
16.	CTU	poor ϕ	cartons	30		"	18	—	0.02
17.	TOLU	good	bales	30		"	100	115	0.25
18.	DAYU	good	cartons	30		"	84	60	0.4
19.	CATU	good	cartons	30		"	132	115	0.17

Containers 3 and 4 (fumigated static) were refumigated after aeration and railment as 18 and 19.

* Condition assessed visually prior to loading: good = suitably gas tight
average = probably gas tight
poor = unsuitable for fumigation (but treated for comparative purposes)

ϕ Polythene lining placed over floor and wall/floor junction

\+ Type of tobacco load and amount : Cartons = 40 x 200 kg
Cases = 34 x 200 kg
Bales = 90 x 200 lbs

Φ Measured in the centre of a load unit i.e. bale, carton or case.

Gas analysis. Phosphine gas concentrations were determined using a Miran 104 portable infra-red gas analyser which had been calibrated against known concentrations of phosphine in air at a wavelength of 8.95 microns. Samples of gas for analysis were withdrawn from the sampling positions through the narrow-bore nylon capillaries using a 100ml gas sampling syringe as described by Webley et al (1981). As an additional check, measurements were made using Draeger gas-detector tubes at selected points at most sampling times.

Results

The concentrations of phosphine 200 hours after application of the fumigant and the associated concentration time (CT) products of phosphine up to 200 hrs in the containers during the course of the trials are given in Table 1. The effectiveness of these in achieving a satisfactory fumigation may be assessed by comparing them with the CT products found to be necessary to achieve control of *Lasioderma serricorne*, the tobacco beetle. Hole et al (1976) showed that against eggs (the most tolerant stage to phosphine) mean concentrations of 0.36mg/ℓ for 4 days at 15°C and 0.1mg/ℓ for 7 days at 25°C were required to achieve near 100% mortality. This corresponds to CT products of 34.6mgh/ℓ and 17mgh/ℓ respectively.

It will be seen from Table 1 that adequate CT products (over 8 days) were achieved in all containers considered to be in good or average condition.

A significant concentration of phosphine remained in the better containers beyond 8 days and this could increase the CT products still further. Containers 9 and 10 in the second trial and 15 and 16 in the third trial were assessed as in poor structural condition and would normally have been rejected. All failed to give a satisfactory CT product despite the addition of polythene lining in 15 and 16. Railing containers under fumigation appeared to increase the rate of gas leakage but this did not result in unsatisfactory fumigations of tobacco in containers of average or good condition.

Figure 1 gives the concentration/time curves for a container in average condition, while Figure 2 compares the mean concentration/time curves for lined and unlined containers.

Discussion

Containers in a sound condition (with no obvious defects such as cracks, holes in the floor or damaged door gaskets) were shown to make satisfactory fumigation chambers for treating tobacco. Even when subjected to movement by rail over a five day period an adequate final CT product was obtained. However, some containers are inevitably in a damaged condition and defects can lead to fumigant leakage which is so rapid that a concentration of phosphine, sufficient to achieve disinfestation of tobacco, is not retained.

Careful inspection and rejection of defective containers is essential if fumigation is to be reliable. The common problem of a worn and leaky wooden floor may be overcome by lining it with polyethylene and applying a high dose of fumigant as specified later in the conclusions. This can be justified in that it increases the CT product achieved and whilst the increase is not essential in good containers it is critical in the older and more battered containers. The results show that with containers in very good condition there is a substantial degree of overkill but, since residue or taint problems are unlikely to arise, this measure is acceptable because the higher level of treatment ensures satisfactory concentrations in packages within containers of less than average condition.The simplest general guide-line to offer is that, as a matter of course, containers in poor condition must be rejected but the floors of all others should be lined if fumigation is intended.

The packaging materials used for the tobacco were either hessian-wrapped bales with a kraft paper liner, wooden crates with kraft paper lining or cartons of double layer corrugated cardboard lined with polyethylene. All types of packaging were found to be sufficiently permeable to permit an adequate CT product at the centre of a load unit of tobacco.

Phosphine can be retained in a good container for a considerable period of time so the risks due to low concen-trations of phosphine leaking from a container must be considered. Eight days after fumigation low concentrations in the order of 0.1mg/ℓ will remain in a container of average condition and nearly 25% of the applied dose of phosphine (e.g. up to 0.44mg/ℓ) remains in good containers where the rate of leakage is minimal. Containers under fumigation placed in a ship's hold could present a potential hazard to the crew members. The results indicate that where fumigated containers are loaded, they should be placed in a hold having ventilation and, for complete safety, a minimum of 12 days should elapse between fumigation of the container and loading in a ventilated hold. However, when fumigated containers are shipped on deck they do not present a hazard to the crew.

The opening of fumigated containers, prior to receipt, for aeration and removal of spent tablets and plates is unacceptable to the tobacco trade because of the risks of theft and reinfestation. The alternative is for the receiver to accept responsibility for the removal and disposal of the spent tablets or plates in the approved manner. In this respect the recently introduced magnesium phosphide plate, which decomposes more readily and completely, is advantageous. Containers under fumigation during transit should carry a warning notice not only for the benefit of the Shipping Companies but also to advise the receiver.

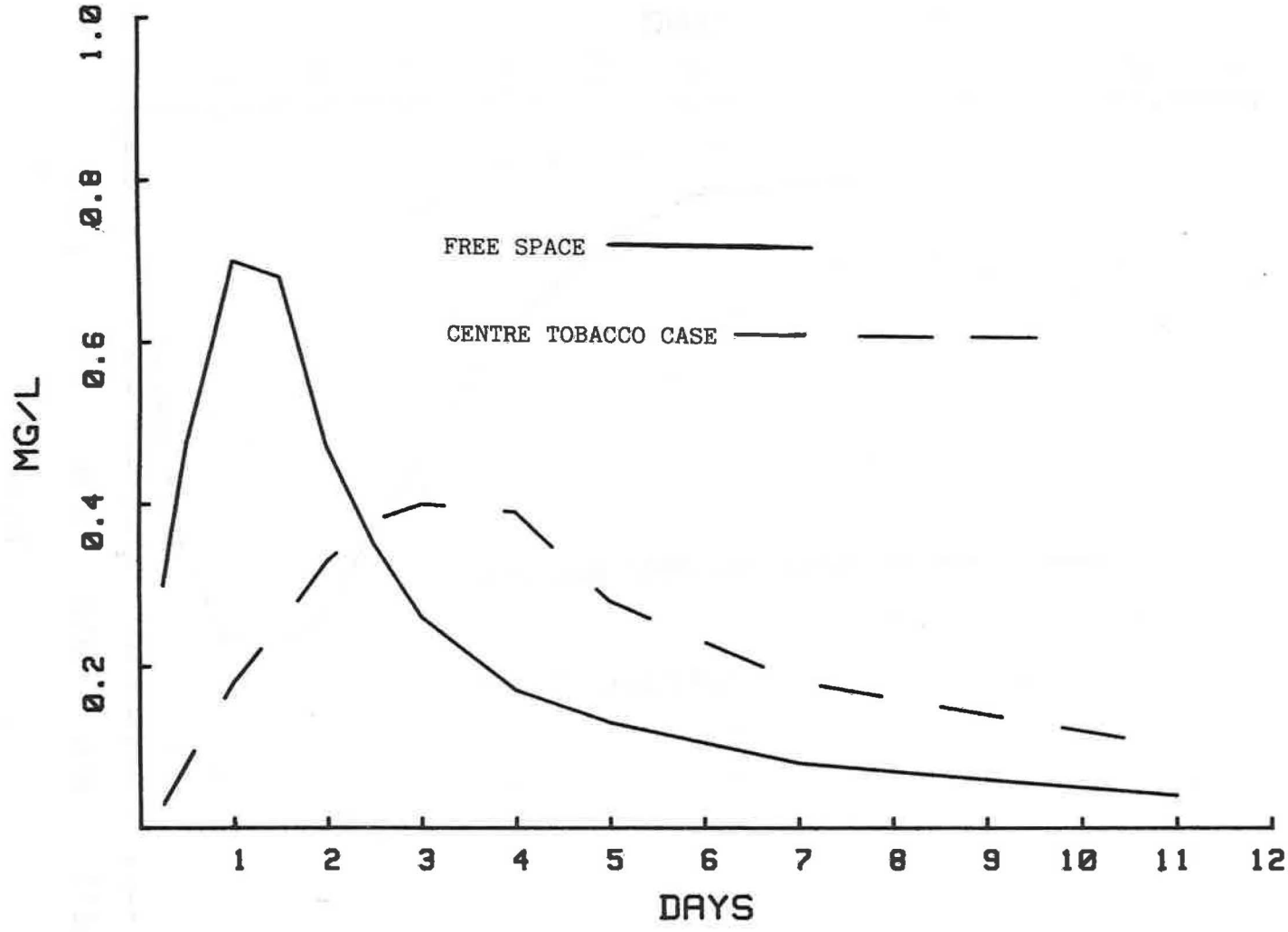

Fig. 1 Concentration/time curves for a container in average condition

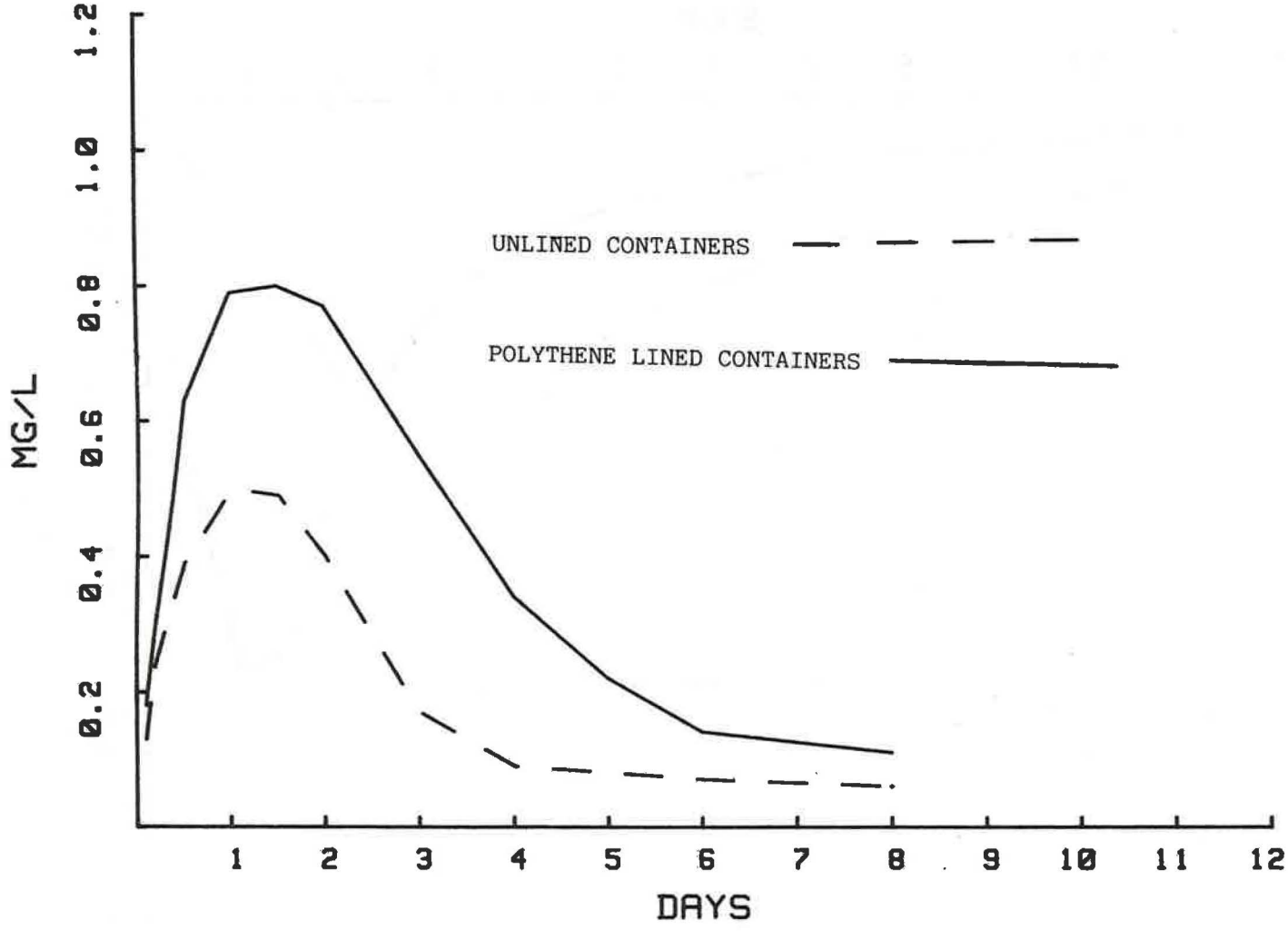

Fig. 2 Mean concentration/time curves for polythene lined and unlined average containers

Conclusions

On the basis of these trials it was possible to recommend the following procedures for the fumigation and transhipment of tobacco in containers.

For Tobacco Companies

1. A careful inspection should be made of containers intended for tobacco which requires fumigation. Containers having defective seams, joints, floors, and gaskets should be rejected.
2. A container with a cracked or worn floor can be made suitable for fumigation by lining the floor with a layer of 125 micron polyethylene film overlaid with cardboard for protection. This simple procedure should be adopted, as a routine, for all containers to be fumigated.
3. All ventilators should be sealed with masking tape.
4. Fumigate the loaded tobacco with either –
   a) 30 tablets (1 tube) phostoxin ($0.9gm/m^3$)
   b) 1 Magnesium phosphide plate ($1gm/m^3$) placed on top of the load adjacent to the door.

   These doses are for a $34m^3$ container; in a $68m^3$ container the dosage should be doubled.
5. Close and secure the doors, affix warning notices to the container and leave it sealed for a minimum of 8 days.
6. On first opening of the loaded container all solid fumigant residues must be removed and disposed of in an approved manner.

For Shipping Lines

1. Fumigated containers should not be loaded on board ship until at least 12 days after fumigation.
2. Fumigated containers must not be opened on board the ship.
3. a) If carried in a hold, then the hold must be ventilated prior to entry of the crew.
   b) If carried on deck, no such precautions are required.

Current recommendations by the Intergovernmental Maritime Consultative Organisation (IMCO) are that fumigated containers must be ventilated before stowage in the holds of ships and any containers still containing fumigant gas should only be stowed on deck. As tobacco companies prefer containers of tobacco to be stowed in holds, so as to avoid possible damage by water, a further set of experiments was undertaken during 1982 (Clarke, 1983) in which phosphine concentrations were measured inside fumigated containers and in the holds in which they were stowed. As before the containers were fumigated in Malawi, but were then railed to Nacala in Mozambique for shipment overseas. It was concluded that fumigated containers which are of sound condition could in fact be stowed below deck in ships' holds without prior aeration, without presenting any hazard to members of the crew. However, for complete safety the hold should be subjected to continuous mechanical ventilation.

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