Improved procedures for fumigation of oaten hay in shipping containers

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Abstract

Oaten hay is compressed and placed in ISO shipping containers for export as animal feed. The standard procedure for fumigation using schedules for grain does not provide complete control, and therefore investigations were carried out on fumigation procedures specific to oaten hay.

The trials reported here were carried out under summer and winter conditions in 12.2 m (40 ft) ISO shipping containers of 67 m^3 volume. Over 100 trials were conducted with and without tarpaulins depending on the level of gastightness of the containers. The fumigants tested were methyl bromide and phosphine.

New fumigation protocols were developed and tested. The results show that effective control is achieved by the uniform dispersal of fumigant throughout the container. There have been no rejections of hay fumigated under the new protocols despite a 10-fold increase in exports since 1987.

Introduction

Export of oaten hay (*Avena sativa*) to Japan is a highly promising industry for Western Australia. It has shown a tenfold increase from an experimental tonnage of 477 t in 1987 to over 48000 t in 1993. The market potential for Australian hay is assessed at 250000 t/annum.

Oaten hay is shipped to Japan for animal feed. The hay is compressed ('double dumped') to improve the weight/volume ratio for shipping in 6.1 m (20 ft) or 12.2 m (40 ft) containers. The most common reason for the rejection of Australian hay has been the presence of live insects, mainly pests of stored grain.

The hay is routinely fumigated before export using phosphine or methyl bromide. These fumigations were not always successful and caused significant monetary losses due to high treatment costs in Japan. The cost of a fumigation in Australia is approximately $70 per container, compared with a rejected container in Japan at $1300/container.

Industry therefore requested investigation of the reasons for failure and development of more effective treatments.

The work program was implemented to meet industry requirements, and the outputs reflect the demands made by industry and other relevant bodies at the time of the research work.

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Existing protocols

Methyl bromide

The application of methyl bromide involves introducing the gas (after a measured volume of the liquid has passed through a heat exchanger) into the container through a slightly opened door. Containers are fumigated in this manner under tarpaulins either singly or in batches of five. The dose rate is 32 g/m^3 for an exposure period of 24 hours. This dose rate should give a *CT* product of 200 g.hours/m^3

Phosphine

Phosphine fumigation requires the placement of 10 aluminium phosphide sachets giving a dose rate of 1.68 g/m^3 (1206 ppm) in the front, near the door, before the container is sealed. Fumigations are done under tarpaulins on concrete pads with an exposure period of 7–10 days.

Materials and Methods

In this paper, only trials conducted in 12.2 m (40 ft), 67 m^3 containers in 'double dumped' bales are reported. These bales are 500 mm long × 400 mm wide × 400 mm high and weigh 42–45 kg depending on moisture differences and compression by the baler. Each container carries approximately 588 bales giving a load of 24.7–26.5 t/container. The gross product volume is 47 m^3 under the most tightly packed conditions, achieving a load factor of 70%.

A purpose-built PVC application pipe was used for administration of both methyl bromide and phosphine sachets. The pipe is the same length as the container and has 4 mm diameter holes drilled at 100 cm intervals starting 200 cm from the door end of the container. The pipe was introduced along the top of the bales through the centre of the container and left in place for the duration of the fumigation.

The trials were conducted in two series. In the first series, containers packed with hay ready for export were fitted with 3 nylon gas sampling lines along the front, middle and rear end of each container. The required treatments were applied, and observations made as frequently as the working environment allowed. The container was released for shipment on the immediate request of the exporter.

In the second series, containers were specially rented for experimental use. Fifty gas sampling lines were introduced into each container to measure gas concentrations uniformly throughout the container; 15 positions in the airspace between bales and 35 positions in the centre of bales. Each container was 'partitioned' into 5 sections along the length and 3 along the width giving a total of 15 sections, which when further partitioned into top, middle and bottom gave 45 units of sampling, each of approximately 1.48 m^3. The 30 sampling units along the length on each side of the container had gas probes placed in the centre of the bales, while the central units

had 5 probes placed in bales occupying the 'centre' position along the entire length of the container. Thus, in each of the 5 cross-sectional partitions of the container, there were 10 sampling lines, 7 in bales (top, middle and bottom) and 3 in air. Temperatures were measured by placing thermistor probes in bales uniformly at 7 locations throughout the container. The probes were connected to a digital data logger placed on the top surface of the container. One external probe measured the ambient temperature outside the container. Temperature records were taken continuously at hourly intervals and the data obtained at the end of each trial were down-loaded onto the hard disk of an IBM computer. All gas sampling lines were drawn to the top surface of the container directly above their position in order to minimise the dead volume in the line.

Gas concentrations were measured at regular intervals by using direct reading instruments (Riken™ interferometer for methyl bromide; and an EC80 Phosphine Monitorô for phosphine), gas detector tubes (Auer™) and gas chromatographs (Varian™ 3400 Series with a flame ionisation detector for methyl bromide; and a thermionic specific detector for phosphine). Cumulative concentration by time products were calculated using the method described by Bond (1989).

The gastightness of test containers was measured by introducing compressed air from a G-size cylinder into the sealed container through an air hose fitted with a shut-off valve. A modified 'finger device' (Sharp and Cousins 1982) of hard plastic tubing was fitted under the door jamb of the sealed container to admit compressed air and to sense the pressure developed. The pressure was measured by a Dwyer Magnahelicô Differential Pressure Gauge series 2000, 250 PaC and required that the needle on the gauge register a deflection of 250 Pa before the gas is turned off. As the pressure drops, the time taken (in seconds) for the pressure to drop from 200 to 100 Pa is measured on a stop watch and is used as the pressure decay value. If the container cannot achieve a 250 Pa deflection, it is deemed to have failed the pressure test and is classed as '0' requiring that fumigations be done under tarpaulins.

The standard treatments of phosphine and methyl bromide were first tested for effectiveness. When these were found to be deficient, improvements were tested through a series of experiments and introduced step by step until a cost-effective method was developed.

Results and Discussion

Problems with existing protocols

Methyl Bromide

The existing protocols are unsatisfactory, Figure 1 shows that placing the application pipe only at the front of a container prevents uniform distribution of the gas. Clearly the concentration at the back of the container will never reach the required *CT* product of 200 g.hour/m^3 and insect control failure will result.

Phosphine

Figure 2 shows that placing the phosphine tablets or sachets only at the front of the container is unsatisfactory as this results in uneven distribution of the gas. Furthermore, the poor state of gastightness of the container makes it impossible for gas concentrations to be held above the required 100 parts per million for 7–10 days.

Improvements to existing protocols

Methyl bromide

A new application technique was developed which involved a purpose-designed 40 mm open ended PVC application pipe described above. Initial application rates were 32 g/m^3 in accordance with the existing protocol. Figure 3 shows more uniform distribution of the gas through the front, middle and back of the container than that shown in Figure 1. It appears that it will take several days before the required *CT* product of 200 g.hours/m^3 is reached.

Another problem identified during the project was that poor gastightness of containers also resulted in fumigation failure. Figure 4 shows that although more even distribution was achieved through the use of the application pipe, the required exposure dose of 200 g.hour/m^3 could not be reached in a leaky untarped container even with an application rate of 100 g/m^3.

Figure 5 shows the improvement resulting from the use of a tarpaulin to cover a leaky container. The 200 g.hours/m^3 dose was achieved after only 6.5 hours.

Some containers are suitable for fumigation without a tarpaulin, provided a pressure test is carried out. Containers which are able to hold the pressure test for as little as 5 seconds can be fumigated without a tarpaulin. Figure 6 shows a

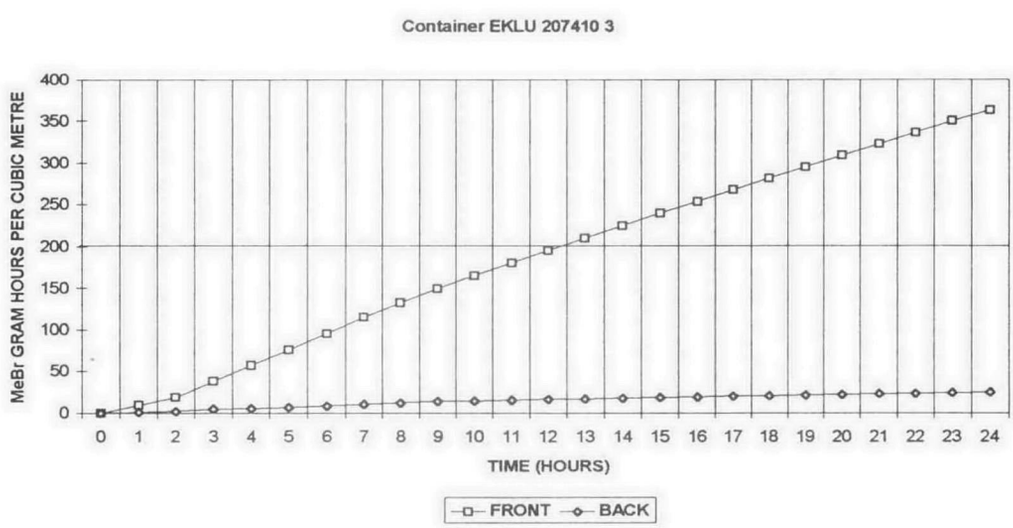

Fig. 1. *CT* product for MeBr fumigation using existing protocol (0 second pressure test, tarpaulin used, 32 g/m^3 dose).

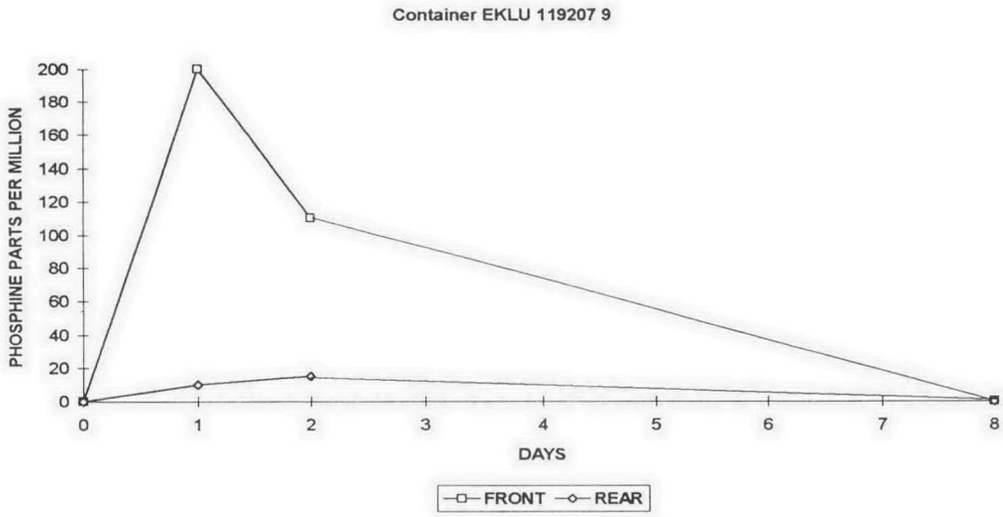

Fig. 2. *CT* product for phosphine fumigation using existing protocol (0 second pressure test, tarpaulin used, 1.68 g/m^3 dose).

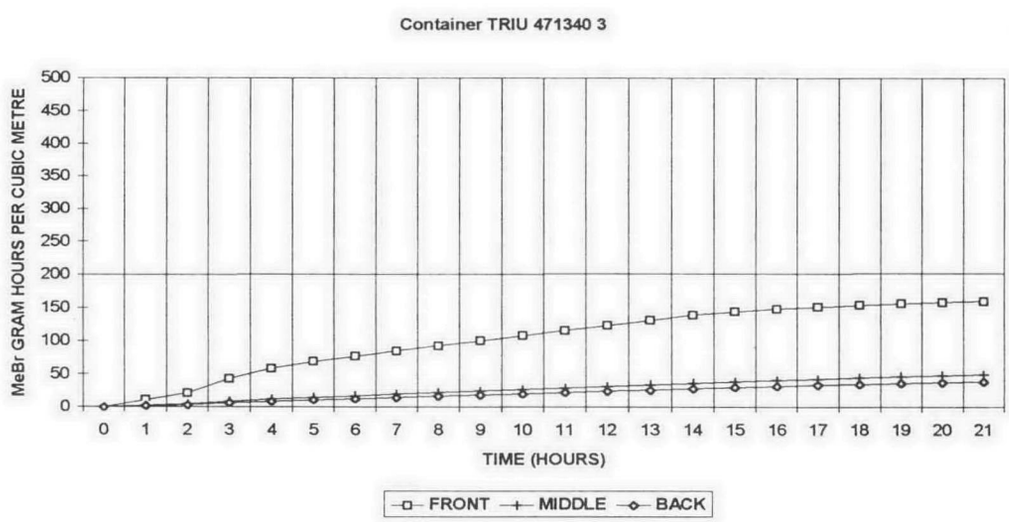

Fig. 3. MeBr fumigation using application pipe (6 second pressure test, tarpaulin not used, 32g/m^3 dose)

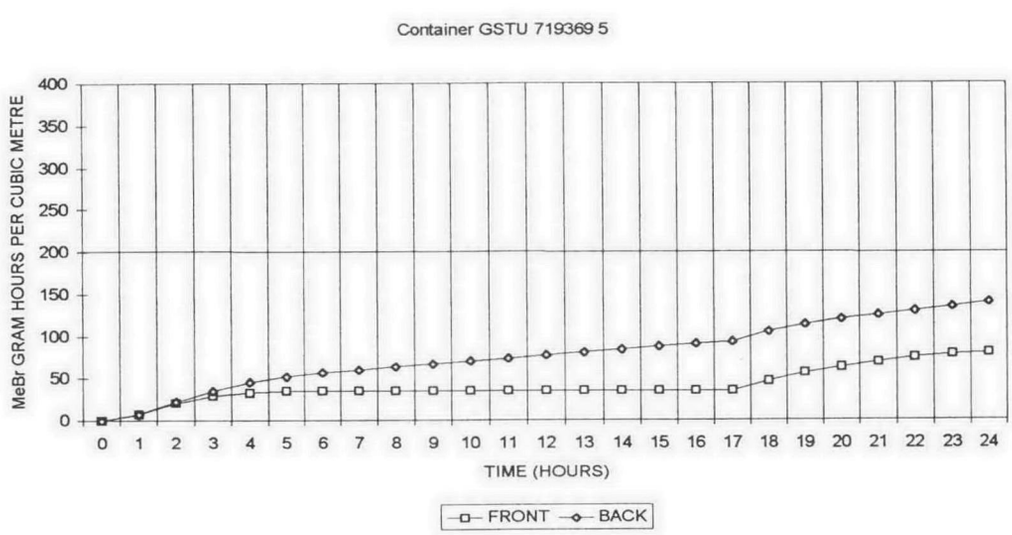

Fig. 4. MeBr fumigation using application pipe in poorly sealed container (0 second pressure test, tarpaulin not used, 100 g/m^3 dose)

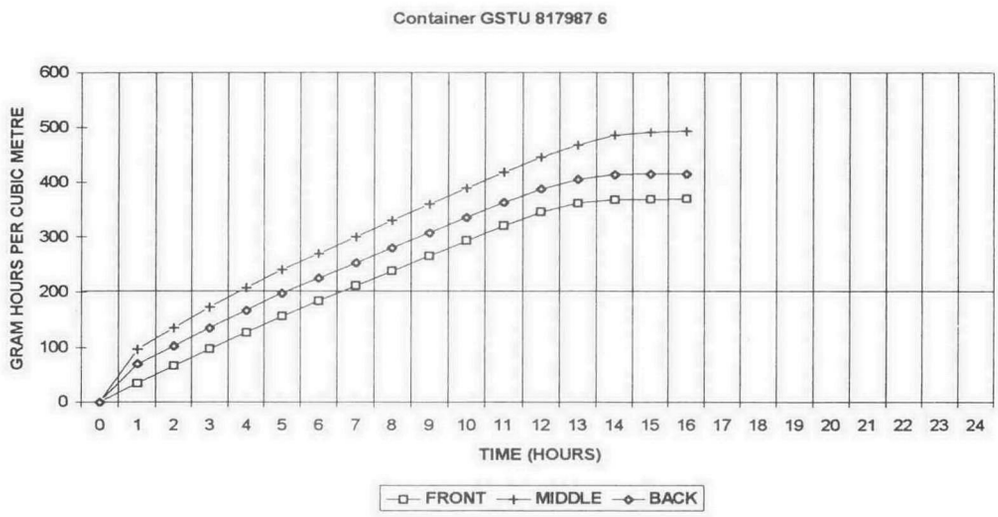

Fig. 5. MeBr fumigation using application pipe in poorly sealed container using tarpaulin (0 second pressure test, 100 g/m^3 dose)

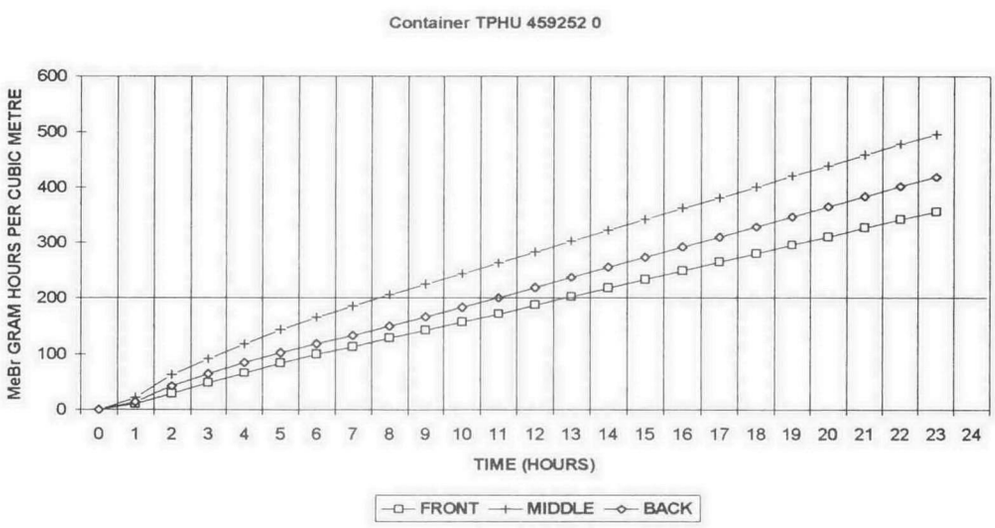

Fig. 6. MeBr fumigation using application pipe in slightly sealed container (3 second pressure test, tarpaulin not used, 48 g/m^3 dose)

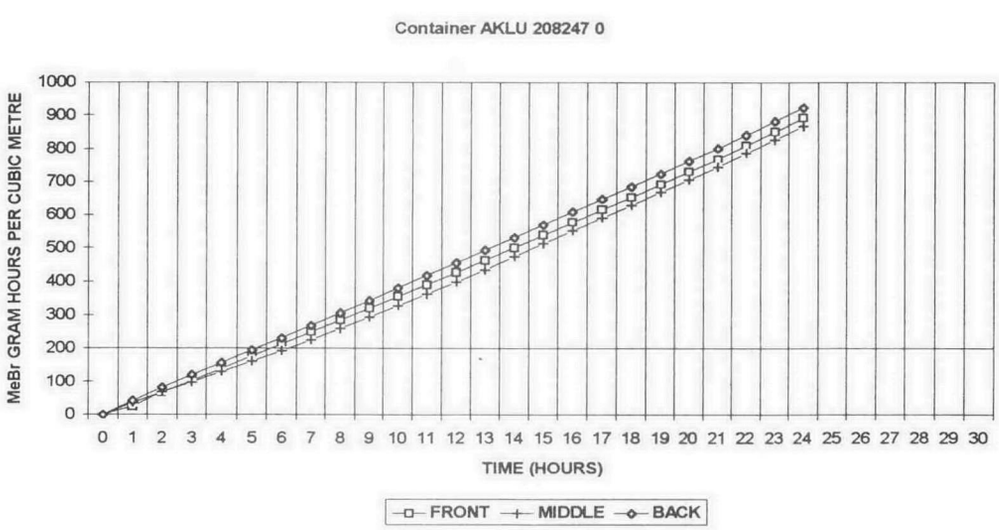

Fig. 7. MeBr fumigation using application pipe in well sealed container (9 second pressure test, tarpaulin not used, 48 g/m^3).

container which held the pressure test for 3 seconds under experimental conditions; insect control was achieved after 12.5 hours. Over 100 containers of varying levels of gastightness have now been tested to confirm these findings.

The existing protocol recommended a dosage of 32 g/m^3, but more than half of the gas is adsorbed by the hay resulting in an inadequate fumigation. A series of trials was carried out to determine a dosage which would overcome the effect of adsorption and maintain sufficient concentration of gas in the airspace to achieve disinfestation. Figure 7 shows the improvement in airspace concentrations resulting from a dosage of 48 g/m^3.

The project had now established that sufficient concentrations of gas could be achieved in the airspace between hay bales throughout the container. The question remained whether the gas would penetrate as readily to the centre of the bale at every position in the container. To answer this 35 probes were placed in the centre of bales which were uniformly distributed throughout the container. A further 15 probes were placed in the airspace between bales.

Figure 8 demonstrates that gas penetrated to the centre of the bales as rapidly as it did through the airspace. Equilibration was achieved within 3 hours at all points within the container and the recommended *CT* product was achieved after 9 hours.

Phosphine

Improvements to the phosphine fumigation protocol required better distribution of the aluminium phosphide sachets. The PVC application pipe described above was used to place four sachets at the front, three in the middle and three at the back of the container. The container shown in Figure 9 held the required pressure for 10 seconds. Clearly, there was uniform distribution of the gas and the concentration was held above 100 parts per million after 7 days. This fumigation successfully controlled all developmental stages of all known stored-product pests.

Having established that phosphine concentration could be held above 100 parts per million for 7 days and that even distribution of the gas could be achieved, the question remained whether phosphine readily penetrated the double dumped hay bales. The 50-point experiment shown in Figure 8 was repeated using phosphine. Figure 10 shows that phosphine readily penetrated the hay bales and that equilibration was achieved within 1 day.

Conclusions

Pressure testing of containers to ensure adequate gastightness is essential for fumigations without tarpaulins.

Effective fumigation cannot be achieved unless special procedures are followed to ensure even dispersal of the fumigant throughout the container.

Both phosphine and methyl bromide readily penetrate into the centre of double-dumped hay bales.

The results of the project have already been put to practical use. Immediate benefits have been a substantial reduction in the number of rejections in 1990–91, and no rejections between 1991–94 even though exports have been steadily increasing each year.

Recommendations

1. Pressure decay test

The containers should be measured for gastightness using the following procedure:

1.1. Use a Dwyer MagnahelicÆ Differential Pressure Gauge series 2000, 250 PaC with piping specified and approved by the Department of Agriculture.

1.2. Introduce the industrial grade compressed air (available in G-size cylinders) into the container until the needle on the gauge registers a deflection of 250 Pa. Then turn off the gas.

1.3. If 250 Pa cannot be achieved the container is deemed to have failed the pressure test and must be fumigated under gastight tarpaulins.

1.4. Gas leakage from the container is indicated by pressure decay as shown on the gauge. Start the stop-watch when the needle drops to the 200 Pa mark.

1.5. Stop the watch when the needle drops to the 100 Pascal mark.

1.6. The time taken is the pressure test value in seconds for the container.

1.7. Pressure testing may be done on full or empty containers. For full containers subtract two seconds from the registered time to give the true value of the container.

1.8. Only containers achieving a pressure test decay time of greater than 5 seconds are deemed to have passed the pressure test and are suitable for fumigation without tarpaulins.

2. Fumigation in containers that meet the pressure test

2.1.Methyl bromide

Tarpaulins are not required for containers that exceed a pressure decay test value of 5 seconds.

Methyl bromide should be applied in the standard way through a heat exchange unit by a licensed operator. The pipe delivering the fumigant should be connected to a 40 mm open ended PVC pipe of the same length of the container. The pipe should have 4 mm diameter holes drilled at 100 cm intervals starting 200 cm from the door end of the container. The pipe should be introduced along the top of the bales through the centre of the container and should be left in place for the duration of the fumigation. This will ensure even distribution of the gas.

Methyl bromide should be applied at the rate of 48 g/m^3 for the following conditions:

Exposure period	Ambient temperature
12 hours	>25°C
24 hours	10-25°C

2.2.Phosphine

Containers that hold pressure for at least 10 seconds are considered to have passed the pressure test and may be fumigated without the use of tarpaulins.

Phosphine may be applied as 10 sachets (34 g each) of aluminium phosphide and inserted into the container using the PVC application pipe described for methyl bromide fumigations. A weighted string can be dropped down the pipe and the sachets attached to the end. This will allow removal of the pipe immediately and the sachets at the conclusion of the fumigation. The sachets should be distributed as four sachets to the rear of container, three sachets to the middle of container and three sachets at the door end of container. At the end of the fumigation period the sachets must be retrieved and disposed of in accordance with the label. The phosphine should be

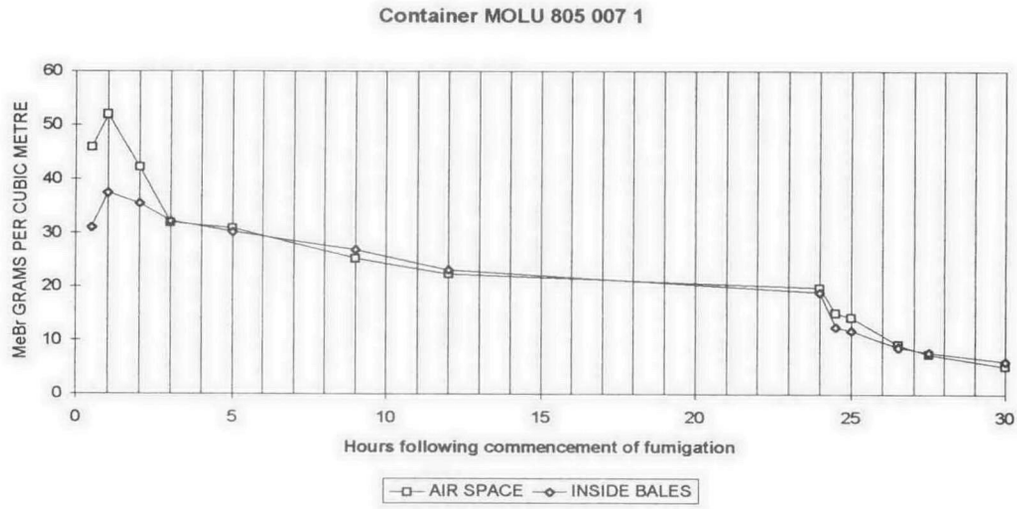

Fig. 8. Comparison of MeBr concentrations in the airspace and within hay bales (8 second pressure test, tarpaulin not used, 64 g/m^3 dose)

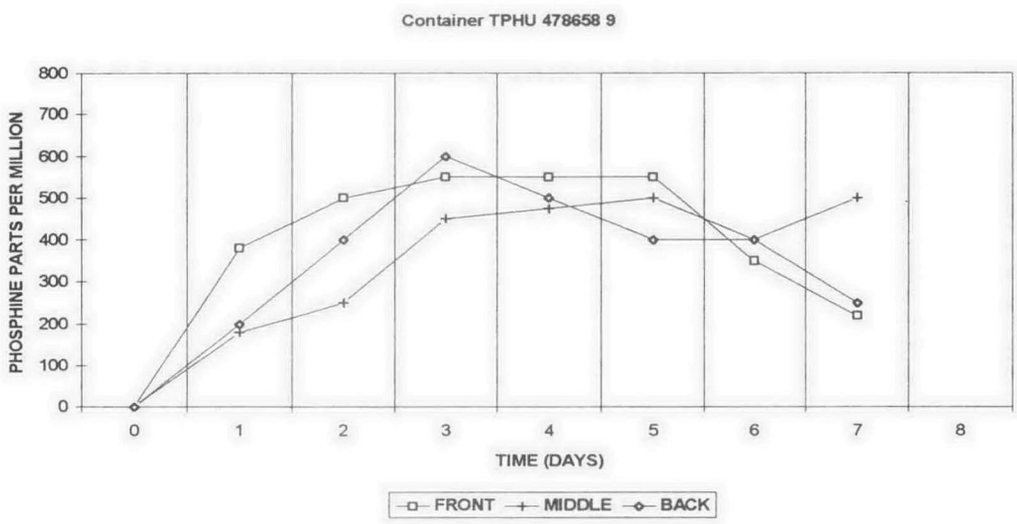

Fig. 9. Phosphine concentration over time in container fumigated with improved protocol (10 second pressure test, tarpaulin not used, 1.68 g/m^3 dose)

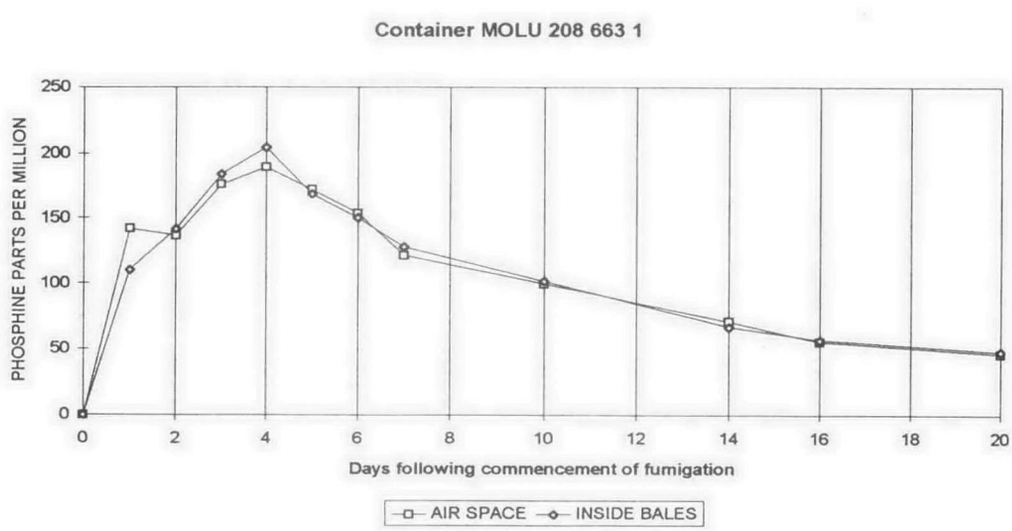

Fig. 10. Comparison of phosphine concentrations in the airspace and within hay bales (16 second pressure test, tarpaulin not used, 1.68 g/m^3

retained for the following exposure periods (Winks et al. 1980)

Exposure Period	Ambient Temperature
7 days	>25°C
10 days	15-25°C

Do not attempt phosphine fumigations if temperatures are below 15°C.

3.Fumigation with tarpaulins in containers unable to meet the pressure test

3.1.Methyl bromide

Containers that do not hold pressure for 5 seconds are considered to have failed the pressure test. The following fumigation specifications then apply.

The containers must be placed on an impervious floor (e.g. cement/concrete) with a minimum of 50 cm edge all around the container. The tarpaulins should be free from holes and made from heavy gauge plastic (greater than 1500 micron) or bitumen-canvas. Tarpaulins should be secured to the sides of the container with ropes. This is to prevent any bellows action in the presence of strong winds which has the effect of pumping the gas out of the container. The tarpaulin should be weighted down with 15 cm diameter sand snakes placed in contact with the container body. The overall cover on the container should be tight to prevent any flexing of the tarpaulins.

Methyl bromide should be applied as described in Section 2.1.

3.2.Phosphine

Containers which cannot hold pressure for at least 10 second are consider to have failed the pressure test and must be fumigated under tarpaulins. Apply the phosphine as described in Section 2.2 and the tarpaulins as described in Section 3.1.

Acknowledgments

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Winks R.G. et al. 1980. Dosage recommendations for the fumigation of grain with phosphine. Science Communication Unit, Standing Committee on Agriculture Technical Report Series, 8.