MINIMAL FUMIGANT REQUIREMENTS FOR LONG-TERM AIR-TIGHT STORAGE OF GRAIN

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ABSTRACT

In large air-tight storage structures, insect control is slow because the relatively large volume of oxygen is not depleted quickly enough to exert control. In Kenya, practical use of large hermetic bins during the past 10 years has shown that effective insect control can be obtained through the use of phosphine gas at the lower limit of the effective concentration determined in laboratory experiments. Complete insect control is achieved at 0.0303 mg/l dosage applied on the whole bin volume.

In developing countries where grain may be stored for relatively long periods of time to meet domestic requirements and long-term famine reserves, the use of low phosphine concentrations in hermetic containers may have economic advantages over controlled atmosphere obtained from the use of nitrogen and carbon dioxide gases.

INTRODUCTION

Traditionally, underground storage of grain under semi-hermetic conditions has been practised in Asia, Africa, Europe and America from pre-historic to recent times (Sigaut, 1980). Practical use of modern large scale long-term semi-underground storage has been made in the past 40 years in Argentina, Cyprus and Kenya.

One of the problems of the use of large scale structures has been the relatively slow rate of insect control under cool conditions (because physiological development is slower and so oxygen consumption less) and under conditions where initial insect populations are small and so consumption of oxygen is negligible in comparison to the large volume of the storage container.

When such conditions prevail, practical experience in Kenya has shown that effective insect control is achieved with the minimal use of phosphine gas.

AIRTIGHT STORAGE IN KENYA

The successful use of 68 large (1500 tonne) hermetic bins in Kenya to store over 100,000 tonnes of maize as a famine reserve has been described elsewhere (De Lima 1980a, b). Maize has been continuously stored in excellent condition in individual bins for up to 4 years. The bins have been used under practical operating conditions for over 10 years. Total gross weight losses have been below 0.3% per year. After 3 to 4 years of continuous storage under hermetic conditions the grain has been sold as top quality, Grade 1. The 68 bins have been used 121 times over a 9 year period. Oxygen depletion in the bins was associated with mould growth in the apical portion of the bin. Maintenance requirements were small and economically attractive in comparison with conventional storages.

EFFECTIVENESS OF MINIMAL USE OF PHOSPHINE

In initial filling (1972) 30 g of hydrogen phosphide were generated by the release of aluminium phosphide tablets (Phostoxin, Degesch, Co., West Germany) or 17.7 g dichlorvos releasing strips were placed at the top and side hatches of the bins before sealing. These were meant to control superficial infestation by *Sitotroga cerealella* and *Ephestia cautella*.

In subsequent sampling some bins were shown to have a residual insect population as may be seen in Figures 1 and 2. The insects were mainly *Sitophilus zeamais*. *Sitotroga cerealella* and *Tribolium castaneum* Samples were taken down the central axis of the bin and gave a higher than normal value of average insect numbers, but the figures are good indications of potential insect problems. As can be seen in Figures 1 and 2 the insects were not controlled by the low oxygen atmospheres and phosphine concentration was below 0.015 mg/l. A second treatment of 60 Phostoxin tablets, 30 at the top and 30 at the side hatch, applied after approximately 26 and 28 months of initial filling gave effective control. This second treatment raised the phospine concentration by 0.0303 mg/l. It is doubtful if sufficient phosphine from the initial treatment remained to augment the second dose.

In later fillings (1973 onwards) 60 Phostoxin tablets were used as described above. The effectivenes of these treatments which gave a long term concentration of 0.0303 mg/l phosphine can be seen in Figures 3 and 4. There was only one isolated record of insects in grain samples (Fig 3) and none in the other bin (Fig 4).

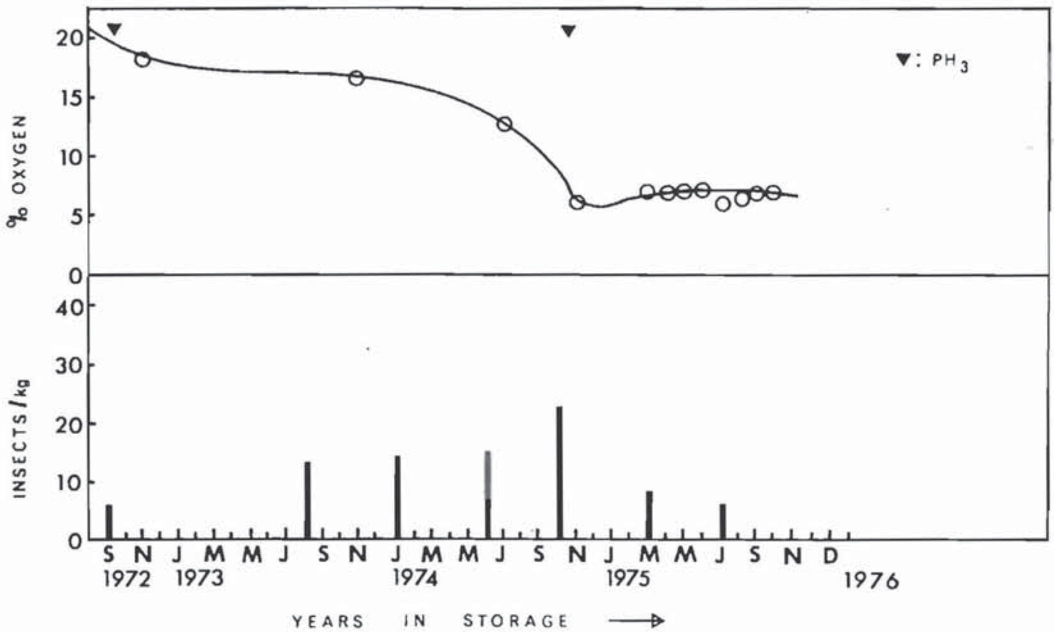

Figure 1. Initial 0.015 mg/l phosphine at filling, followed after 26 months with 0.0303 mg/l phosphine for complete control (Bin No. 40, Kitale).

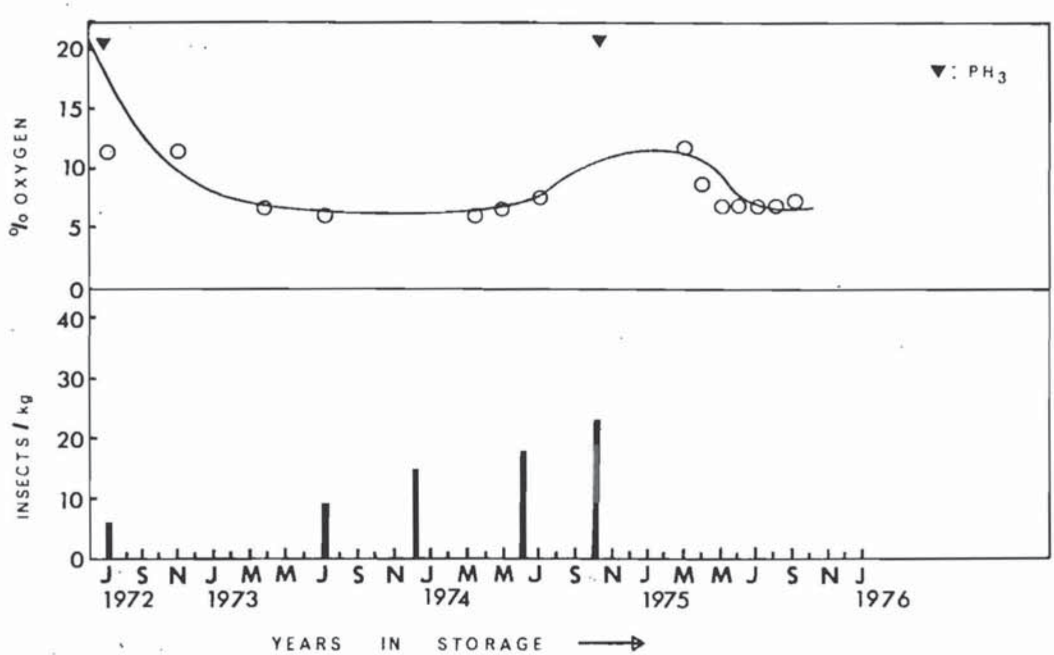

Figure 2. Initial 0.015 mg/l phosphine at filling, followed after 28 months with 0.0303 mg/l phosphine for complete control (Bin No. 33, Kitale)

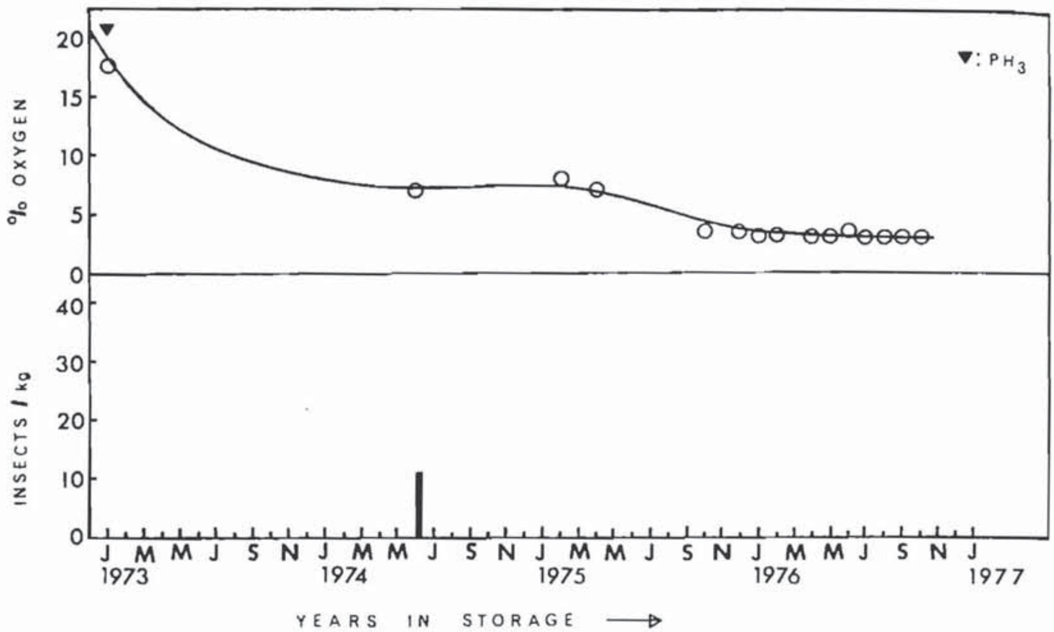

Figure 3. Effective control with single initial dose of 0.0303 mg/l phosphine. Isolated insect record after 18 months (Bin No. 12. Nakuru).

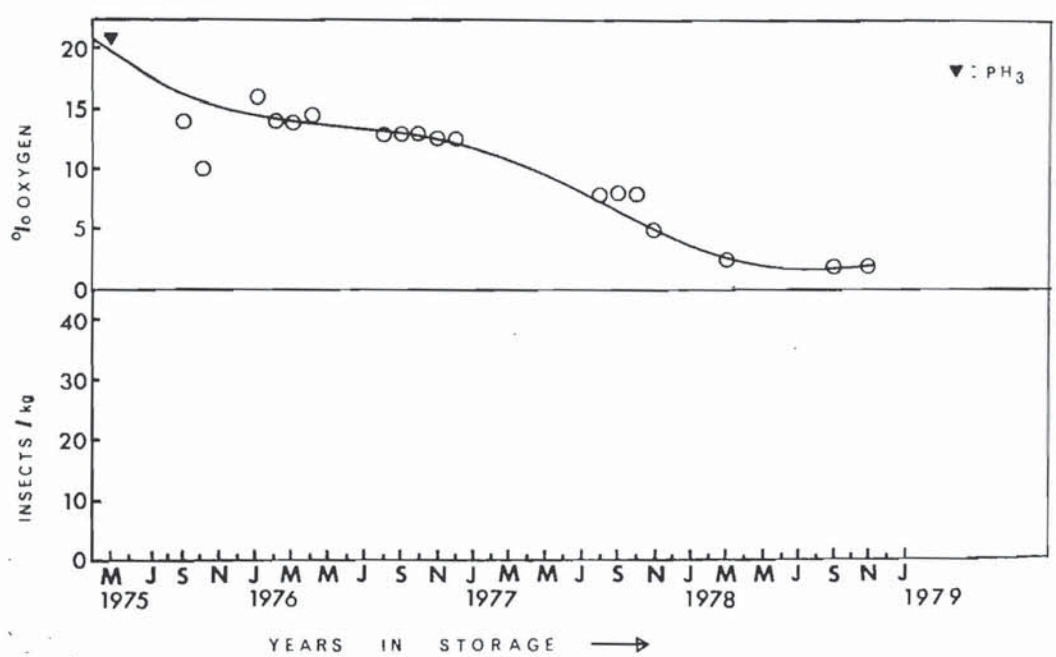

Figure 4. Effective control with single initial dose of 0.0303 mg/l phosphine (Bin No. 20. Nakuru).

DISCUSSION

Howe (1974) has reviewed at length various aspects of laboratory investigation of the toxicity of phosphine to stored product insects in an attempt to explain variations in results from field experiments. Part of the variability in laboratory and field trials is a result of varying susceptibility to phosphine by the different stages of the insect's life cycle (Bell 1976). This may be compounded in field trials with variations in daily temperatures especially if the trial is for a short period of time. Nakakita et al. (1974) obtained 100% mortalities of adult *Sitophilus zeamais* in the laboratory (at 25°C) within a 24 hour period at 25 ppm phosphine (approximately 0.035 mg/l) a value only slightly above that achieved in the Kenya hermetic bins. The presence of oxygen in the hermetic bins may be an advantage in enhancing the toxicity of phosphine to the insect pests. This has been demonstrated under laboratory conditions by Bond et al. (1967, 1969) and Chefurka et al. (1976). In a study of the toxicity of phosphine to diapausing larvae of *Ephestia elutella*. Bell (1979) found that (at 20°C) phosphine achieved peak efficiency at concentrations of 0.04 - 0.01 mg/l using a concentration - time product of 14 mg hr/l for 100% kill.

The length of exposure time for phosphine has not received much experimental attention. The need for this and the difficulties involved have been discussed by Howe (1974). Hole et al. (1976) have shown that long exposures are necessary for the control of tolerant insect species. Higher concentrations of phosphine produce narcosis (causing paralysis) permitting insects to survive longer because the fumigant inhibits metabolism (Nakakita et al. 1974).

In general however, Bell (1979) states, work over the past several years has shown that with phosphine, duration of exposure is more critical than gas concentration for ensuring insect control.

In the hermetic bins in Kenya the phosphine concentration used is 0.0303 mg/l and the time of exposure is several months. The experimental evidence in the literature discussed shows that the concentration of 0.0303 mg/l is at the lower end of the range required for control. However because of the hermetic conditions and the long exposure periods very large concentration x time products are achieved enabling complete control of insect pests.

In recent work, the use has been advocated of carbon dioxide and nitrogen atmospheres to artificially reduce the oxygen content of a storage container before finally sealing it. This approach has some economic merits in european countries where large quantities of grain are required to be harvested and stored at high moisture levels. The approach is advantageous in countries that are primary exporters of grain and are limited by nil tolerance requirements of insects and pesticide residues on their exported commodities. In developing countries such restrictions do not apply to locally consumed produce and the requirements are practically impossible to achieve because grain is received from large numbers of primary producers and is already infested at harvest. Under such conditions the use of minimum levels of phosphine in air-tight structures is an attractive option.

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