

FUMIGATION TRIALS WITH CARBON DISULPHIDE:CARBON TETRACHLORIDE (20:80) IN SILO BINS

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Abstract: Trials were carried out in Shanghai, China to develop a simple fumigation system for silo bins. Preliminary experiments in the laboratory and on a pilot scale showed that carbon disulphide: carbon tetrachloride (20:80 % w/w) was an effective fumigant against *Sitophilus zeamais*, *Tribolium castaneum* and *Cryptolestes pusillus* at a rate of 331 g m^{-3} for a 7 day exposure period at about 29°C grain temperature. A dosage of 220 g m^{-3} under similar conditions gave incomplete control. It was found that the fumigant mixture applied to the grain surface in two sealed test bins (height 30m) at 331 g m^{-3} gave complete control of test insects placed in the grain close to the surface (test insects included immature stages of *T. castaneum* and pupae of *S. zeamais*). Both fumigant components rapidly penetrated the grain mass and were retained at substantial concentrations for more than ten days.

1. INTRODUCTION

The main type of grain storage structure in China are rectangular warehouses ('flat storage'). These have been widely used in the past and there is much experience in pest control in such structures. However, recently silo bins have been built in coastal areas for storage of imported grain and for export. This paper describes trials carried out in Shanghai between June 1981 and October 1982 to develop expertise in insect control in such unfamiliar structures. The treatment investigated used $\text{CS}_2:\text{CCl}_4$ (20:80) as a fumigant under gravity penetration.

2. LABORATORY TESTS

Wheat (4kg, 13.6% m.c.) was treated with $\text{CS}_2:\text{CCl}_4$ (20:80) (2.136 g) in glass bottles of 6.45 L capacity at 26° . The tests were carried out in 3 replicates. Each test included 100 adults, 20 pupae and 20 larvae of *Sitophilus zeamais* Mots. The adult insects started to be knocked down after 1.5 hours exposure. After 72 hours all adult insects were dead*. There was no mortality in

* Editor's Note: No information is given on the response of the immature stages to the treatment.

untreated control samples. The grain was normal in colour and odour.

3. PILOT SCALE TESTS

Two wheat bulks, each of 75 tonnes, were treated with CS₂:CCl₄ (20:80) applied by watering can to the grain surface. The surface of each bulk was covered with 3 layers of hemp mats and then sheeted with polyethylene sheet (0.23 mm thickness), leaving a headspace of 3 m³. The grain temperature was 28 to 29°C and the air temperature 31.7°C. One bulk, of 90m³ total volume and 5 mm depth, was treated with 19.8 kg (220 g m⁻³) of fumigant mixture. The other of 83 m³ volume, was treated with 27 kg (331 g m³) fumigant mixture. The wheat piles remained covered for 7 days to ensure effective fumigation.

Caged insects were placed in the upper, middle and lower part of the treated grain bulks. There was no survival of adult insects in the bulk treated at the higher dosage. The test insects included *S. zeamais*, *Tribolium castaneum* Herbst and *Cryptolestes pusillus* Schon. There was some survival of *T. castaneum* adults in the bulk treated at 220 g m⁻³. The higher dosage seems more appropriate.

Caged rats were placed at distances of 5, 10, 15 and 20 m from the treated piles to indicate leakage of toxic gas. There were no deaths in these test rats, showing that the plastic sheeting was effective in producing a sealed structure.

4. FULL SCALE TESTS

Full scale tests were carried out in June and September 1982 on imported wheat (13% m.c.) in two silo bins. The larger bin, No. 101, was 8 m diameter and 29.3 m high, volume 1180 m³, and contained 863 tonnes of wheat. The smaller bin, No. 201, volume 534 m³, contained 394 tonnes. The grain temperature at the time of treatment ranged from 26 to 30°C in the upper layer and was at 25°C in the middle and lower layers of the grain mass.

4.1 Method of bin sealing

The bins were not gastight. The top and bottom of the bins were sealed with paper stuck to the structure with resin plaster. Some small leaks still remained in the wall, base and outlet. A pressure test gave a pressure decay time of 4.5 mins for 500 mm H₂O to 200 mm H₂O.

4.2 Test insects

S. zeamais (adult and pupae), *C. pusillus* (adult), *Rhyzopertha dominica* (F.) (adult) and *T. castaneum* (all stages) were used as

test insects. Six probe tubes, 3 m long, were inserted into the grain. The probes contained cages of each different species with 20 insects and feed in each. Probes were removed at daily intervals after the first 48 hours after treatment. The test cages were examined, incubated and then re-examined after 15 to 30 days to determine insect mortality.

4.3 Fumigation method

CS₂ and CCl₄ were weighed out appropriately and mixed in a 200 kg capacity tank to give an 20:80 (w/w) mixture to be applied at 331 g m⁻³. The mixture was sprayed onto the surface of the grain in the silo bins from the tank which was pressured with CO₂ at 0.5 kg cm⁻² from a gas cylinder.

4.4 Gas sampling positions and frequency

Gas samples were taken at five points in the bin: in the head-space 0.05 m above the grain, 3 m below the surface, 12.5 m below the surface, 28.5 m below the surface and at the base of the bin. Semirigid polyethylene tubing attached to the temperature sensor cable was used for gas sampling. Gas concentrations were determined three times within 48 hours of dosing and then daily until the storage was vented.

4.5 Method of ventilation

The fumigant was removed by forced ventilation in bin No. 101. The bin was already equipped with cross flow ductwork and a large fan (5.5 kW, 350 mm H₂O d.p., 2400 m³h⁻¹). Fumigant was pumped from bin No. 201 with an old vacuum pump as no ventilation system was fitted.

4.6 Results

4.6.1 *Effectiveness against insects.* There was no survival of any test insects for 7 to 10 days exposure with a dosage of 66 g m⁻³ CS₂ + 265 g m⁻³ CCl₄ (See Table 1).

4.6.2 *Gas distribution.* With the fumigant mixture applied to the grain surface, high concentrations of CS₂ and CCl₄ were detected throughout the bin after 24-32 hours with peak concentrations reached after 32-48 hours.

4.6.3 *Operation.* The method of treatment was easy and safe. The total of mixed fumigant used, 400 kg, was prepared in 11 mins.

4.6.4 *Fumigant residues.* Fumigant residues were determined after airing. 0.2 ppm CS₂ and < 4.1 ppm CCl₄ remained.

4.6.5 *Environmental safety* Gas samples were taken from each floor in the silo. Only two of the 32 samples exceeded the standard level.

5. DISCUSSION

5.1 The mixed fumigant ($\text{CS}_2:\text{CCl}_4$) was effective. The use of the mixed fumigant reduces the fire hazard.

5.2 Table 2 shows the penetration and spread of the fumigant. The distribution achieved was good with the mixed gas penetrating more than 30 m downward.

5.3 In China, the gastightness of silos is not good. Although some preventative measures are used, leakage still occurs. It is expected that there will be improvements made in gastightness.

TABLE 1.

Mortality (%) and location of test insects in bin No. 101.

Location in bin	east	west	north	south	centre	centre
Period of exposure (days) ^a	2	3	4	5	6	7
<i>S. zeamais</i>						
adult	100	100	100	100	100	100
pupa	100	100	100	100	100	100
<i>T. castaneum</i>						
adult	100	100	100	100	100	100
egg	100	100	100	100	100	100
larvae	100	100	100	100	100	100
pupa	100	100	100	100	100	100
<i>R. dominica</i>						
adult	100	100	100	100	100	100
pupa	100	100	100	100	100	100
<i>C. pusillus</i>						
adult	100	100	100	100	100	100
pupa	100	100	100	100	100	100

^a Fumigation started on June 26, 1982.

TABLE 2.
Fumigant vapour concentration (g m^{-3}) at various times (bin 101).

Fumigant	Location in bin	6 hr	24 hr	32 hr	72 hr	96 hr	120 hr	144 hr	168 hr	192 hr	216 hr	240 hr	264 hr
CS2	headspace	271	34	28.5	9.9	9.9	4.9	2.8	2.6	1.1	0.55	0.55	0.55
	upper	70	90.2	89.7	51.2	58.3	35.8	30.3	32.5	19.5	19.8	22.8	17.6
	middle	138.6	121	121.6	78.1	88	59.4	31.4	50.6	45.1	34.1	42.6	33.8
	lower	1.7	61	62.2	46.8	60	46.2	42	49	37.7	38.5	46.5	38
CCl4	headspace	361	52.8	47.3	19.8	17.6	6.6	3.3	3.3	2.2	2.2	2.2	2.2
	upper	39.6	128.7	124.3	67.1	84.7	46	41.8	39.6	30.8	29.7	30.8	24.2
	middle	92.4	223.3	212	124	151.8	85.8	48.4	70.4	63.8	57.2	69.3	51.7
	lower	2.2	104.5	114	79.2	111	73.7	74.8	71.5	61.6	61.6	77	59.4