Current Strategies for the use of Controlled Atmospheres for the Disinfestation of Grain under UK Conditions

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Introduction

Two aspects critical for the use of controlled atmospheres for disinfestation of grain under U.K. conditions are their efficacy at low temperatures and their cost. Of a total U.K. grain storage capacity of about 26 million tonnes, some 8 million tonnes are provided by bins. Grain coming into store is usually dried to below 16% moisture content (m.c.) soon after arrival, and then cooled by forced aeration to below 10°C. However, residues left from the previous harvest often give rise to infestation. Cooling of the bins below 10°C effectively prevents further breeding or development but substantial numbers of adults may be found wandering in the new grain. Eventually these will start to breed in any area of localised heating originating from microbiological or mechanical activity. The control of adult pests is thus often the primary objective at low temperatures.

The performances of modified atmospheres based on carbon dioxide (CO_2) and on the exhaust from burning propane were compared in laboratory and farm-scale trials.

Tests on Storage Pests in the Laboratory

Atmospheres were produced by passing gas fed from cylinders through a 'Signal' gas blender and conditioning the stream to 70% relative humidity at the experimental temperature. With CO_2 concentrations down to 40% in air, 2 weeks exposure at 10° or 15°C was sufficient to kill all stages of the psocids *Liposcelis bostrychophilus* and *Lepinotus patruelis*, and adult beetles of *Cryptolestes ferrugineus, Rhyzopertha dominica, Oryzaephilus surinamensis, Sitophilus granarius, S. oryzae,* and *Tribolium castaneum* (Table 1). A similar exposure to the burner atmosphere (10–15% CO_2, 1% oxygen, and 84–89% nitrogen) killed the last four species at both temperatures but 3–4 weeks exposure was required for *C. ferrugineus* and *R. dominica*. Mortality of the batches of 100 insects was assessed 7 days after return to air.

Purging of Grain Bins

The 19 m^3 welded steel bins sealed to give an applied pressure half-life of 2–20 minutes were set up with wheat at 14.4%, 15.1%, and 16.0% m.c. at 15°±2°C. Each was purged with simulated burner gas at the rate of 5 L/minute for up to 3 days (two atmosphere changes), by which time oxygen levels had fallen to 1%. The 16% m.c. bin maintained the atmosphere without further supply of gas for seven days (Table 2), during which time oxygen levels were held below 1%, probably as a re-

Table 1. Time (days) for control of adult beetles and all stages of psocids with CO_2 at 10° and 15°C

Species	CO_2 range (% in air)	10°C	5°C
Sitophilus granarius	40–95	10	8
	100	>10	14
S. oryzae	40–95	7	4
Cryptolestes ferrugineus	40	>8	12
	60–100	10	7
Rhyzopertha dominica	40–100	11	8
Oryzaephilus surinamensis	40–100	7	5
Tribolium castaneum	40–100	7	6
Liposcelis bostrychophilus	40	>8	12
	80–100	10	>7
Lepinotus patruelis	40	>8	6
	80–100	9	8

Table 2. Maintenance of a typical exhaust gas atmosphere in 19 m^3 bins (pressure 50% decay time 2.5 min) loaded with wheat of different moisture contents.

Purge time (days)	Flow rate (L/min)	CO_2/O_2 levels at wheat surface		
		14.4% mc	15.1% mc	16.0% mc
0	5	0/21	0/21	5/14
1	5	4/12	4/11	10/4
2	5 → 1	11/2.3	11/2.4	15/0.2
3	1 → 0.5	11/1.5	11/1.5	15/0.1*
4	0.5	–	12/1.3	15/0.2*
6	0.5	13/1.3	12/1.1	14/0.9*
7	0.5	13/1.2	13/1.1	14/0.7*
9	0.5 → 0.25	13/1.0	13/1.1	15/0.8*
10	0.25 → 0.5	13/1.3	13/1.6	15/0.8*
14	0.5	13/1.1	13/1.1	15/0.8*

*Gas flow stopped at 72 hours.

sult of micro-biological activity. The atmosphere in the other bins was successfully maintained by a reduced gas flow of 0.5 L/minute (one atmosphere change every 2 weeks).

Similar tests were conducted with CO_2 on wheat at 14% m.c. in three free-standing galvanised metal plate bins sealed to give pressure half-lives of 5, 30, and 60 seconds. The last standard was achieved only by dismantling and rebuilding the bin. To maintain nearly 100% CO_2 throughout the 5 sec. bin in wind speeds up to 2 m/sec, an atmosphere change was required every 18 hours. CO_2 was supplied from new 'minitanks', each producing 70 m^3 of gas. When the flow was shut off, CO_2 in the 5 sec. bin dropped to below 50% in somewhat less than 24 hours, while the 30 and 60 sec. bins required 4 and 10 days, respectively, for a similar fall.

Conclusions

The gas produced by burning propane kills adult beetles within four weeks at 10°–15°C, while CO_2 requires only 2 weeks and remains fully effective down to less than 50% in air. Despite these advantages, burner gas is still a considerably cheaper method of achieving control, provided that a burner is available. Farm bins are not sufficiently gastight for one-shot CO_2 treatments, a pressure half-life of at least 1 minute being required for a 10-day exposure, together with calm weather. For both CO_2 and burner gas, continuous flow systems offer the only practical method to achieve control. Any measures which can increase the gastightness of bins towards a 30 second half-life pressure test result are likely to be cost effective but achieving a higher standard may not be practicable for existing storages.