SULFURYL FLUORIDE TO REPLACE METHYL BROMIDE USE IN THE FLOUR MILLING INDUSTRY

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Sulfuryl fluoride (SF) is being investigated as an alternative to methyl bromide (MB) for use on certain commodities and in structures such as flour mills. Unlike MB it is inorganic and harmless to the ozone layer. The gas is almost insoluble in water, is non-flammable, and has a high vapour pressure (boiling at -55^{o}C). It has potential advantages over many other candidate chemicals; it is non reactive with structural materials and electronic equipment and, although high doses are needed to kill eggs, it has a rapid action against pests. Furthermore, it seems that eggs may be able to continue development during exposure to the gas and that their susceptibility increases towards hatching. This suggests that increasing the duration of the exposure or raising the temperature to speed development may help to improve efficacy against eggs (Bell and Savvidou, 1999). Unpublished research (Dow AgroSciences) indicates that SF penetrates wheat flour much more efficiently than MB, which is a significant benefit in situations where insect infestations are located deep within flour-packed cracks or machinery. If a control agent lacks these penetrating capabilities, re-infestation of other areas occurs very rapidly, severely undermining the value of a fumigation treatment.

The principal pests of mills in Europe are the Mediterranean flour moth *Ephestia kuehniella* (MFM), the rust-red flour beetle *Tribolium castaneum* (RFB), and flat grain beetles of the genus *Cryptolestes*, notably *C. turcicus*. *Tribolium confusum* and *Tenebrio molitor* occur widely but usually in smaller numbers. In the USA pests such as the warehouse beetle *Trogoderma variabile* (WB) and the saw toothed grain beetle *Oryzaephilus surinamensis* are also commonly encountered. Efficacy data and trials data from flour mills are needed for registration of SF to be pursued in Europe, and Dow AgroSciences is working in partnership with research groups and industry.

Studies on different insect species agree that the egg is the stage of highest tolerance (Kenaga, 1957; 1961; Outram, 1967; Su and Scheffrahn, 1990; Williams and Sprenkel, 1990; Thoms and Scheffrahn, 1994; Drinkall *et al.*, 1996). Kenaga (1957) presented data on the toxicity of SF to eggs of seven species of beetles and moths at 80^{o}F, Thoms and Scheffrahn (1994) add a further nine, and Drinkall *et al.* (1996) another five, including *E. kuehniella*. The last named authors also demonstrated that other life stages were highly susceptible to the gas. The current report discusses the effect of temperature on the efficacy of SF against eggs of three important species, *E. kuehniella, T. castaneum* and *T. variabile*, in relation to flour mill fumigation. Some tests were also conducted on the larval and pupal stages of *E. kuehniella* and *T. castaneum*.

Methods

E. kuehniella was reared on a 10:2:1 mix of wheatfeed, glycerol and dried yeast powder at 25°C, 60-65% r.h. in a 16 hr light, 8 hr dark lighting regime. *T. castaneum* was reared on whole wheat flour with 5% added yeast while *T. variabile* was reared on a mixture of whole wheat and wheatfeed, at 25°C, 60% r.h. Groups of 200 adult beetles were set up on fine flour and incubated at 25°C, 60% r.h. for three days. Moths were set up in a sieve with access to drinking water under similar conditions but the timing of "lights out" was manipulated to obtain eggs early in their second day for the fumigation exposures. For each species, the eggs laid were counted out on watch glasses in batches of 50 for the experimental replicates. For egg tests these were set up for fumigation in petridishes containing rearing food medium. For tests on larvae or pupae eggs were added to 100 ml count jars with food to incubate at 25 °C until arrival at the required stage. Fumigations were conducted in 1700 litre specialist insect toxicity test chambers and gas concentrations were monitored by gas chromatography.

Results and discussion

Pupae and larvae of *E. kuehniella* and *T. castaneum* were all killed by concentration x time products (CTP) lower than 100 mg.h/l at 25 and 30°C. In contrast, eggs of these species and those of *T. variabile* required substantially higher dose levels for control. Increasing temperature from 20 to 30°C greatly increased the efficacy of SF, enabling CTP's to be reduced by a factor of approximately 5-fold, depending on the species. Insect development, temperature, concentration thresholds for effective action and length of exposure time control the results obtained. CTP's effective against the egg stage of stored product insects have been achieved in recent trial fumigations of flour mills. From these results and those obtained on insect eggs, it can be concluded that SF fumigation of flour mills offers a viable alternative to fumigation with MB. In cool temperate climates some heating of mills will be necessary to ensure that dosages which can readily be achieved in practice will reach the level required for kill of all stages.

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