How to overcome the egg-weakness of sulfuryl floride – combinations of control methods

Christoph Reichmuth* and Dagmar Klementz

Institute for Ecological Chemistry, Plant Analysis and Stored Product Protection,
Federal Research Institute for Cultivated Plants,
Koenigin-Luise-Str. 19, 14195 Berlin, Germany
[* christoph.reichmuth@jki.bund.de]

1. Description of the weakness of SF and possible solutions

As supported by plenty of laboratory and field results, the fumigant sulfuryl fluoride (SF) needs plenty of more dosage to control the egg stages of pest insects than the other stages. Apart from some preferable qualities of this gas in comparison with methyl bromide, this is a typical and specific constraint when using SF alternatively against pest arthropods and limits its feasibility. The bioassay of the exposed insect samples after SF treatment often shows eventually surviving insects after long observation periods without survivors, because the surviving eggs need long time for development into adults. The differences in response to SF between the different life stages expressed as relation between the lethal ct products are in the range up to factor 15 of three selected species as shown in table 2. Also, the temperature at locations where the insects may be hiding can be elevated to enhance the efficacy of a poison by accelerating metabolic activity, uptake and mode of action. Since other fumigants and the use of heat are more or less equally effective against eggs and other life stages - with pupae and diapausing larvae often being the most tolerant stadiums - the idea is obvious to investigate as to how far a combined use of two or more lethal factors may offer complete control and a reduction of cost and amounts of applied toxic chemicals.

Examples for combinations exist for other gases. For instance low concentrations of phosphine were suggested together with about 5 vol.-% of carbon dioxide and elevated temperature of about 35°C to overcome the risk of corrosion caused by the regular fumigation with high concentrations of phosphine (patent Mueller 1995). The combination of carbon dioxide with elevated pressure also offers an alternative to the use of carbon dioxide alone. This combination shortens the lethal exposure period against pest insects from weeks (without pressure) to hours (at about 20 bar) (Mitsura et al. 1973, Stahl et al. 1985, patents Corinth and Reichmuth 1991). Long exposure can be prohibitive in various situations of pest control.

Eventually, even the expansion of exposure time with SF over 72 h may lead to better efficacy against all present stages because tolerant eggs may develop into susceptible young larvae during the fumigation. This approach is of course only in such situations applicable where time is not a big constraint. It would reduce the necessary lethal ct product significantly.

2. Combinations of fumigants

2.1. **Combination of sulfuryl fluoride with hydrogen cyanide**

Hydrogen cyanide has been used more than hundred years ago for pest control (Peters 1942, Monro 1969, Bond 1984, Mallis 1990). In Germany 7 g/m³ in 3 days were registered for this purpose in combination with phosphine for fumigation in stored product protection. Some years ago, Reichmuth carried out investigations on the efficacy of the combined gases sulfuryl fluoride and hydrogen cyanide against stored product pest insects (unpublished data, that are presented here). Also, the patent of Baeumert and Belt (2002) contains combinations of 20 g/m³ of sulfuryl fluoride and 1.5 g/m³ of hydrogen cyanide proposed for the control of all stages of *Tribolium castaneum*, *Ephestia kuehniella* and *Sitophilus granarius* at 25°C (table 1).

In practice, the Desinsekta company in Germany has successfully applied a combination of 2 g/m³ of HCN and about 30 g/m³ of SF within 40 hours, including some additional dosage of SF depending on losses due to leakage.

2.2. Sulfuryl fluoride and carbon dioxide

The Institute for Stored Product Protection# has also tried combinations with carbon dioxide and sulfuryl fluoride for pest insect control (table 3). Obviously, the combination of the two compounds increased the efficacy significantly. So, it seems to be promising to investigate this effect in more detail.

2.3. Sulfuryl fluoride and phosphine

Since phosphine is nearly equally effective against eggs and pupae and even more against adults, a combination of this gas with SF might deserve investigation and be promising in cases where corrosion is not a constraint.

2.4. Combination of sulfuryl fluoride and heat

The combination of sulfuryl fluoride and heat (≈ 35°C) increases the efficacy of the gas against all life stages of insects including the eggs (table 2). Equal warming up of a premise for fumigation may safe some gas without jeopardizing the success of the treatment. The optimal combination concerning concentration and dosage of SF and the degree of warming has to be determined.

3. Conclusion

Laboratory and field data support the approach to combine other fumigants or heat with sulfuryl fluoride to ensure the complete control of all egg stages in the course of disinsectisations.

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References

Baeumert, K., Belt, H.-J. (2002). Synergistische Schädlingsbekämpfung [Synergistic Pest Control]. Patent DE 101 10 570 A 1, 4 pp.

Bond, E. J. (1984). Manual of Fumigation for Insect Control. FAO Plant Production Paper 54, 432 pp.

Corinth, H.-G., Reichmuth, Ch. (1991). Procedure and installation to disinfest organic bulk material. Patent of the Federal Republic of Germany, No. 0417430.

Mallis A. (ed.) (1990). Handbook of Pest Control. Franzak and Foster Co., Cliveland, Ohio USA, 1152 pp.

Mitsura, A., Amano, R., Tanabe, H. (1973). The acaricidal effects of compressed gas treatments on the grain mite *Tyrophagus putrescentiae*. Shokuhin Eisagaki-zasski 14, 511-516.

Monro, H. A. U. (1969). Manual of Fumigation for Insect Control. FAO Agricultural Studies 79, 381 pp.

Mueller, D. K. (1995). Patent on phosphine, carbon dioxide and heat against stored product pest insects. Quoted in Mueller, K.D. (1998). Stored Product Protection … A Period of Transition. Insects Limited, Inc. Indianapolis, Indiana, USA, 352 pp.

Peters, G. (1942). Die hochwirksamen Gase und Dämpfe in der Schädlingsbekämpfung [The highly effective fumigants for pest control]. Verlag von Fedinand Enke in Stuttgart, 143 pp.

Stahl, E., Rau, G., Adolphi, H. (1985). Entwesung von Drogen durch Kohlendioxid-Druckbehandlung (PEX-Verfahren) [Disinfestation of drugs by pressure treatment with carbon dioxide and expansion (PEX-procedure)]. Pharmazeutische Industrie 47, 528-530.

Tab. 1: Av. Number of survivors of all tested life stages of *Tribolium castaneum* (Tc) and *Sitophilus granarius* (Sg) after treatment over 48 h with sulfuryl fluoride (SF) alone, hydrogen cyanide (HCN) alone, or a combination of SF and HCN, at room temperature and 65% r.h.

SF concentration 20 g/m³, no HCN	SF concentration 20 g/m³, combined with 1.5 g/m³ HCN	no SF, 1.5 g/m³ HCN
average number of survivors, counted as adults (Tc/Sg) after 12 weeks		
4/4	0/0	6/9
Untreated: 40/71		

Tab. 2: Lethal ct products (ctp) for different species and life stages

species	temperature in °C	ct product for complete control in gh/m³		ctp_{eggs}/ ctp_{other}
		eggs	post embryonic stages	
*Ephestia kuehniella**	25	912	83	11
*Tribolium castaneum**	25	1669	113	14.8
*Sitophilus granarius**	25	966	65	14.9
*Ephestia kuehniella***	15	3301		
*Tribolium confusum **	25	780		
*Trogoderma variabile***	25	936		
*Tribolium castaneum***	25	1154		
*Plodia interpunctella****	30	227-1180		
*Tribolium confusum ****	25	910- 950		
*Plodia interpunctella*****	25	624		
*Ephestia kuehniella*****	20	1440		

*According to Bell, C. H., Wontner-Smith, T. J., Savvidou, N. (2003).
8th International Working Conference on SPP in York, UK, 2002, 910 - 915.

** According to Bell, C. H., Savvidou, N., Wontner-Smith, T. J. (1999).
7th International Working Conference on SPP in Beijng, P. R. China, 1998, vol. 1, 345 - 350.

*** According to Schneider B. M., Hartsell P. L. (1999).
7th International Working Conference on SPP in Beijng, P. R. China, 1998, vol. 1, 406 - 408.

**** According to Reichmuth, Ch., Schneider B., Drinkall M. J. (1999).
7th International Working Conference on SPP in Beijng, P. R. China, 1998, vol. 1, 416 - 422.

Tab. 3: Mortality of *Sitophilus granarius* (eggs, larvae) after fumigation with SF, a combination of SF and CO_2 or pure CO_2, respectively, at 20°C

exposure time in h at 20°C	SF concentration 10 g/m³, no carbon dioxide	SF concentration 11.1 g/m³, combined with 50 vol.-% CO_2	no SF, pure CO_2
	Mortality in %		
48	5	45	10
72	41	86	13