INFLUENCE OF TEMPERATURE AND CTP ON FLOUR BEETLE EGGS AFTER SULFURYL FUORIDE FUMIGATION

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For European and French millers, the ban of methyl and the loss of dichlorvos (DDVP) are very problematic to disinfest their structures. Currently, sulfuryl fluoride (ProFume®, DowAgrosciences) is the only fumigant registered since 2006 for flour mills fumigation in France. This gas began to be used at commercial scale in 2007. However, the main drawback of this compound, compared with methyl bromide, is the ovicide efficacy which needs much more gas than the 20 g/m^3 of methyl bromide used in France before its withdrawal.
The most tolerant life stage of flour beetles. with sulfuryl fluoride is the egg stage (Bell et al, 1998), that's why it is necessary to make flour mill's fumigations with dosages higher than those used for MB. This kind of practice can be expensive for millers and the cost of the fumigation is quite often a barrier to the use of ProFume®. However, there is a huge difference between the dosages which ensure to control post embryonic stages of insect pests, and those able to kill the egg stage, particularly eggs of flour beetles. Moreover, the eggs of red flour beetle are more tolerant to sulfuryl fluoride than the eggs of confused flour beetle (Bell *et al*, 1998).
This study is set up to investigate the impact of flour mills fumigations with sulfuryl fluoride at different dosages and temperatures encountered in commercial fumigations on egg's populations of red flour beetles and confused flour beetles.

Material and methods

The trials were carried out in four flour mills, with different conditions of gastightness, injected gas amounts, temperature, speed of wind...
In laboratory, adults of the two species, red flour beetles and confused flour beetles, were put in 20 litres plastic drums with one kilograms of wheat flour. After one week in controlled conditions (27°C and 65% R.H.), insects have laid eggs in the flour and there were in the drums a mixed aged eggs between few hours to seven days. The drums were closed but there was a gap in the lid closed with a Whatman® paper in order to have an air exchange but no insects circulation between the inside drum and the outside.
The drums containing the adults and eggs were placed at different levels of the mills just before the injection of ProFume®. All drums were equipped with a temperature/R.H. data logger Captsystemes® and a sampling gas pipe was placed on the top of the drum. The dosage of sulfuryl fluoride was determined according to the Fumiguide® or at much lower values in order to have several CTPs. After the fumigations each drum was put in controlled conditions, in a rearing chamber (25°C and 60% R.H.). For the controls, the adults were taken

out the drums in order to stop the egg laying. After two months, the flour was sifted in order to count the adults resulting from the eggs at the moment of the fumigation. These results were compared with the adult populations in the controls and then, a percentage of reduction in emergence of eggs compared with control was calculated for each modality.

Results and discussion

The results show that the CTP reached 310 to 1345 g.h/m^3 and the temperatures recorded in the drums during the fumigations were between 19.6 to 34.1°C (Table 1). The percentage reduction in emergence of confused flour beetle eggs is always higher than that of red flour beetle, these results confirm others studies (Bell *et al*., 1998).

The percentage reduction in emergence of confused flour beetle eggs, is more important when there was a high temperature (more than 30°C) in the mill during the fumigation or when the CTP obtained was important (more than 1000 g.h/m^3) (Figure 1). However, in a situation where the CTP obtained and the recorded temperatures were low, the percentage of mortality can decrease as low of 20%. It is obvious on the second chart that there is difference of sensibility between the two species of flour beetles (Figure 2). Comparing with the previous results, when the temperature during the fumigation is below 25°C, the efficacy of the fumigation is not very good even if the CTP is high. With a low temperature below 23°C and a low CTP (about 330 g.h/m^3), the efficacy is very bad, not different of the that observed in the control. As a result, the temperature appears to be the main factor which leads to a good ovicide efficacy on red flour beetle eggs. An increase in temperature of few degrees shows direct effects on the efficacy of fumigations on flour beetles. eggs. In the two cases, when the average temperature during the fumigation was 30°C or more, between 65 to 100% of eggs were killed depending on the conditions.

Conclusion

This study confirms other studies (Reichmuth *et al*., 2003), the dosage can be reduced “intelligently” with good results for stored products fumigation. With low dosages, even if the fumigations do not kill all the eggs of red flour beetles, the treatment may control all or almost all stages of other species of insect pests. It is therefore a good alternative to replace dichlorvos. May be the best way consists to combine the fumigations, with low dosages of sulfuryl fluoride, with heat in order to reach 30°C inside the mills before and during the fumigation, but the economic impact of this combination needs to be assessed.

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Table 1 : Efficacy against confused flour beetle and red flour beetle eggs according to temperatures and CTP recorded during the four flour mills fumigations with sulfuryl fluoride

Temperature (°C)	CTP ($g.h/m^3$)	Reduction in emergence of confused flour beetle eggs (% compared with the control)	Reduction in emergence of red flour beetle eggs (% compared with the control)
19,6	Between 1200 et 1400	99,7	43,4
21,2	1345	100	74,5
21,3	853	100	76,3
21,9	1145	99,9	61
22,4	1016	100	60,8
22,9	331	26,2	0
25,5	308	45,6	18,8
25,5	1192	100	97,4
25,6	351	55,4	11,3
25,6	381	62,6	26,2
25,7	358	66,2	8,3
27,8	1154	100	99,9
30,7	633	100	100
30,9	1134	100	100
31,6	256	99,5	67,8
31,6	1133	100	100
32,5	226	95,3	68,2
32,7	204	95,9	67
33,8	258	99,3	90,5
34,1	163	97,2	65,5

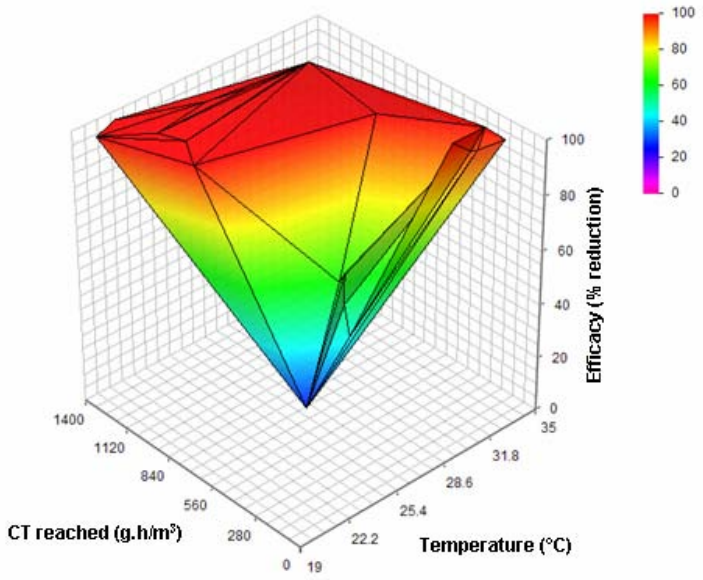

Figure 1 : Percentage of reduction in emergence of confused flour beetle eggs (compared with control) according to CTP reached and temperature during flour mill fumigations with sulfuryl fluoride

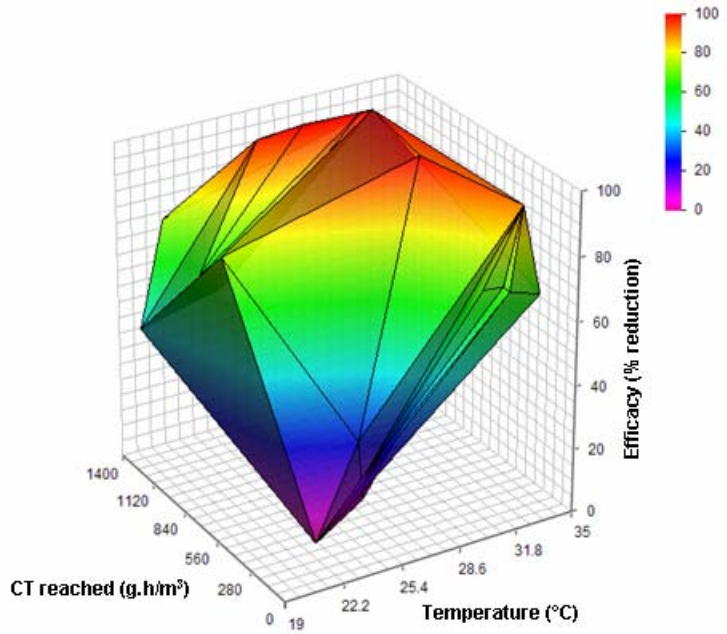

Figure 2 : Percentage of reduction in emergence of red flour beetle eggs (compared with control) according to CTP reached and temperature during flour mill fumigations with sulfuryl fluoride