METHYL BROMIDE, SULFURYL FLUORIDE AND HEAT: EFFECTIVENESS AGAINST RED FLOUR BEETLE

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Researchers at Kansas State University, Purdue University, and USDA's Center for Grain and Animal Health Research in Manhattan, KS, received a grant two years ago to determine cost effectiveness of methyl bromide (MB), sulfuryl fluoride (SF), and heat treatment for managing insects associated with food-processing facilities, primarily flour mills. This research involved evaluating the three technologies in the Hal Ross pilot flour mill of 9268 m^3 volume at Kansas State University. This facility offered the ability to do side-by-side comparisons of all three pest intervention methods within a given month on three separate occasions during 2009-2010. In commercial facilities such comparisons are difficult, because whole facility treatments usually occur on major holidays and only one of the three methods is used at any given time. Therefore, comparing one method to the other in such circumstances can produce misleading conclusions. In May and August 2009, and May 2010, all three methods were evaluated in the Hal Ross flour mill for their ability to control eggs, young larvae, old larvae, pupae, and adults of the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), a pest commonly associated with flour mills.

Insect bioassay boxes

In order to gauge the effectiveness of MB, SF, and heat, a bioassay box with 12 compartments was used (Fig. 1). Eggs, young larvae, old larvae, pupae, and adults of the red flour beetle, along with a temperature sensor were placed into separate compartments of the bioassay box. In these boxes two levels of sanitation were simulated—dusting of flour (good sanitation) and 2 cm deep flour (poor sanitation). Each compartment held 50 individuals of a particular life stage. Boxes were placed in 25 locations of the mill across all five floors. Eleven boxes were placed on the floor while the remaining 14 were placed inside different pieces of equipment.

Pest intervention methods

The mill was subjected to MB, SF, and heat (from forced air gas heaters) during May and August 2009, and May 2010. Each treatment lasted 24 hours. MB and SF gas monitoring lines were placed at each bioassay box to measure gas concentrations over time. Temperatures were monitored in more than 40 locations during the heat treatment.

Pest mortality assessment

After each treatment, boxes were brought back to the laboratory. Boxes containing eggs, young larvae, old larvae, and pupae along with flour were transferred to 150 ml round plastic containers with perforated lids. These containers were placed in growth chambers at 28^{o}C and 65% RH until adult emergence. Mortality was based on number of adults that emerged out of the total (50) exposed. Adults were not transferred to boxes, but were examined after 24 hours to determine mortality.

Efficacy assessment results

The amount of SF used was 3X that of MB. The concentration x time (*Ct*) products for the three MB treatments ranged from 268 to 327 g-h/m^3 (Table 1). During SF treatments, *Ct* products ranged from 663 to 1191 g-h/m^3. For the three heat treatments, 4883 to 5500 liters (L) of propane were used. The *Ct* products attained were influenced by ambient temperatures, which ranged from 22 to 32^{o}C during the MB and SF treatments. During heat treatments, mill temperatures started at 20^{o}C and in a few locations, the highest temperature recorded was 68^{o}C.

Mean mortality of red flour beetle life stages in all MB treatments was 100%, except for the egg and large larval stage (99.9 and 99.8%, respectively) (Table 2). In all SF treatments, 100% mortality was achieved for adults, pupae, large larvae, and small larvae. Mortality of eggs was <100% with all three treatments; however, differences in egg mortality among the three pest management treatments were not significant. The only significant difference among treatments was evident with adults, large larvae, and small larvae in compartments with 2 cm deep flour. During heat treatments the mean mortality of these three life stages ranged from 90 to 96%, and this level of mortality was significantly lower from that observed with MB and SF. These results indicated that sanitation is important for enhancing the effectiveness of heat treatments.

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Figure 1. Bioassay box showing 12 compartments. The top compartments each had 2 cm deep flour (43 g) and the bottom compartments had a light dusting of flour (~0.5 g).

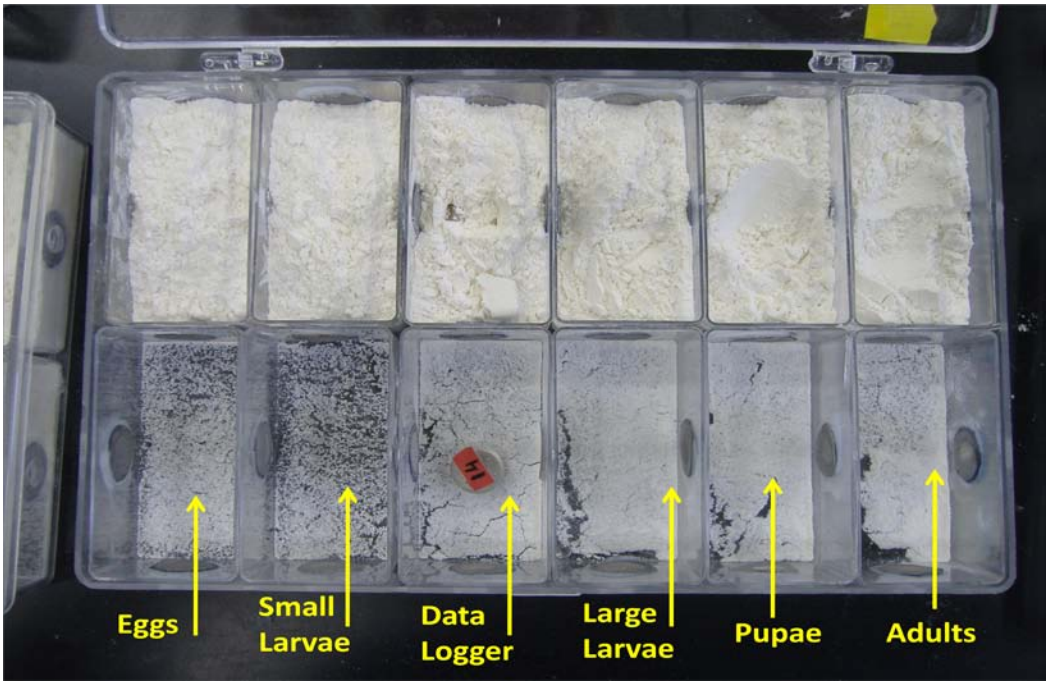

Table 1. Basic information on MB, SF, and heat treatments in the Hal Ross flour mill.

Treatment		Kg of gas used or L of propane used	Mill temp. (^{o}C)	CT product (g-h/m^3) or heating rate (^{o}C/h)
May 2009	MB	181.6	22 - 23	283 - 327
	SF	568.0	23 - 26	923 - 1191
	Heat	5299.6	21 - 67	≤ 3.1
Aug 2009	MB	158.9	27 - 31	268 - 318
	SF	511.2	28 - 32	663 - 1003
	Heat	4883.2	24 - 64	≤3.9
May 2010	MB	199.6	23 – 26	186 - 238
	SF	623.7	27 - 30	1124 - 1371
	Heat	5500.2	20 – 68*	≤4.8

*The maximum temperatures attained, except in a few locations, during heat treatment were ≤60^{o}C.

Table 2. Mean mortality of red flour beetle life stages exposed to MB, SF, and heat.

Insect stage	Sanitation level	Treatment	Mean (SE) mortality[a]	F[b]	P
Adults	2 cm	MB	100a	69.90	<0.0001
		SF	100a		
		Heat	90.1 (1.2)b		
	dusting	SF	100	1.00	0.4219
		MB	100		
		Heat	98.7 (1.3)		
Pupae	2 cm	MB	100	2.56	0.1568
		SF	100		
		Heat	95.4 (2.9)		
	dusting	MB	100	1.00	0.4219
		SF	100		
		Heat	97.3 (2.7)		
Large larvae	2 cm	MB	99.8 (0.1)a	8.62	0.0172
		SF	100a		
		Heat	96.1 (1.3)b		
	dusting	MB	99.9 (0.1)	1.73	0.2552
		SF	100		
		Heat	98.2 (1.3)		
Small larvae	2 cm	MB	100a	5.39	0.0457
		SF	100a		
		Heat	93.5 (2.8)b		
	dusting	MB	100	3.69	0.0901
		SF	100		
		Heat	99.4 (0.3)		
Eggs	2 cm	MB	99.9 (0.1)	1.02	0.4145
		SF	92.3 (7.3)		
		Heat	99.3 (0.3)		
	dusting	MB	99.9 (0.1)	1.25	0.3523
		SF	88.7 (10.0)		
		Heat	99.8 (0.1)		

[a]Means followed by different letters are significantly different ($P < 0.05$; REGWQ test).
[b]The degrees of freedom (df) for all one-way comparisons by sanitation level are 2, 6.