Controlling Red Flour Beetle

Effectiveness of methyl bromide, sulfuryl fluoride, and heat.

Researchers at Kansas State University (KSU), Purdue University, and USDA's Center for Grain and Animal Health Research in Manhattan, KS, received a grant two years ago to determine the 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 at KSU which covers a volume of 9,268 cubic meters.

Side-by-side comparisons were performed in this facility with all three pest intervention methods within a given month, on three separate occasions during 2009-10.

Such comparisons are difficult in commercial facilities, 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 another in such circumstances can produce misleading conclusions.

In May and August 2009 and in 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*, a pest commonly associated with flour mills.

Pest Management

Dr. Bhadriraju Subramanyam

Insect Bioassay Boxes

In order to gauge the effectiveness of MB, SF, and heat, a bioassay box with 12 compartments was used (**Figure 1** on page 33). Eggs, young larvae, old larvae, pupae, and adults of the red flour beetle, along with a temperature sensor, were placed into separate compartments in 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 individual beetles at a particular life stage.

Boxes were placed in 25 locations in 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 the three treatment periods. 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 degrees C and 65% relative humidity, until adult emergence. Mortality was based on the number of adults that emerged out of the total (50) immature insects 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 three times that of MB. The concentration x time (*Ct*) products for the three MB treatments ranged from 186 to 327 g-h/m^3 (**Table 1**, page 34). During SF treatments, *Ct* products ranged from 663 to 1371 g-h/m^3.

Ct is a standard way to express concentration over time where g = grams of gas and h = hours in time and in a given volume that is expressed in cubic meters.

For the three heat treatments, 4,883 to 5,500 liters of propane were used. The *Ct* products attained were influenced by ambient temperatures, which ranged from 22 to 32 degrees C during the MB and SF treatments. During heat treatments, mill temperatures started at 20 to 24 degrees C, and in a few locations, the highest temperature recorded was 68 degrees 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**, page 34). 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 filled 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.

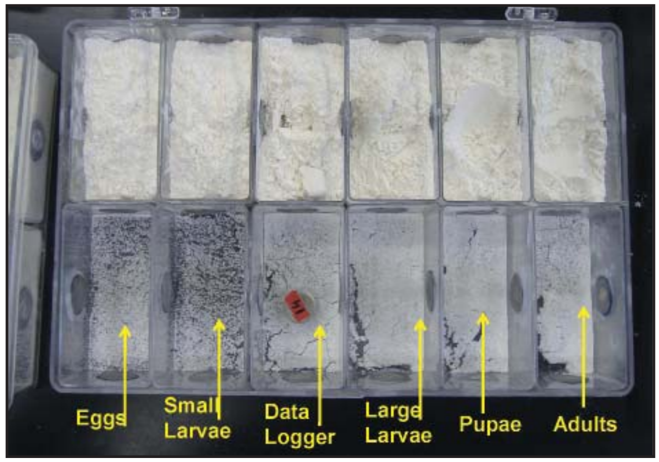

Figure 1. Bioassay box showing 12 compartments. The top compartments each had 2 cm deep flour (43 g), and the bottom compartments had a light dusting of flour (approximately0.5 g).

Conclusions

All three treatments performed well against red flour beetle life stages.

With SF, egg survival was evident in a majority of the compartments with dusting and 2 cm deep flour for the very first treatment, because the mill temperatures were below 27 degrees C (80 degrees F).

The effectiveness of SF against eggs could have been improved by increasing the exposure time beyond 24 hours, by adding more gas, or increasing the temperature.

We wanted to restrict the treatment time to 24 hours for all treatments, and therefore, extending treatment time was not an option.

The amount of gas available at the site was not enough to achieve the *Ct* products to obtain 100% egg kill. The second and third SF treatments resulted in egg survival in only a few compartments of the bioassay boxes, and this was accomplished simply by maintaining mill temperatures at or above 27 degrees C.

The survival observed with heat treatment for all stages was primarily on the first floor of the Hal Ross floor mill. The first flour has large covered roll stands (product zones), which retarded air movement, and this lack of proper air circulation resulted in less than 100% mortality for all stages.

Like SF, with heat, the very first treatment was less effective than the subsequent two treatments. For the second and third heat treatments, the hatch on the roof was opened, and this permitted satisfactory air movement and improved insect kill.

Although MB was the most effec- ►

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. (°C)	Ct product (g-h/m3) or heating rate (°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 degrees C.*

tive of the three treatments against all life stages of the red flour beetle, our results suggest that SF and heat are viable MB alternatives for the future.

Bhadriraju Subramanyam (Subi) is a professor in the Department of Grain Science and Industry at Kansas State University, Manhattan. He can be reached at 785-532-4092 or sbhadrir@k-state.edu.

TABLE 2 Percent 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 or Ryan-Einot-Gabriel-Welsch statistical test).*
[b] *The degrees of freedom (df) for all one-way comparisons by sanitation level are 2, 6.*