Cost comparison of Methyl Bromide and Sulfuryl Fluoride (ProFume®) for fumigating food processing facilities, warehouses, and cocoa beans

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DOI: 10.5073/jka.2010.425.167.133

Abstract

Costs of fumigating a food processing/warehouse facility using methyl bromide and sulfuryl fluoride (ProFume®) were compared using an economic-engineering approach. The two fumigants were also compared for fumigating cocoa beans. Sulfuryl fluoride is economically feasible for cocoa beans. It is economically feasible for some, but not all, applications in food processing facilities and warehouses.

Keywords: Economics, Cost, Benefit, Fumigation methyl bromide, Sulfuryl fluoride, ProFume®

1. Introduction

Methyl bromide (MB) has been used for more than 50 years to control insects, nematodes, pathogens, and weeds. However, the parties to the Montreal Protocol classified it in 1992 as an ozone-depleting substance, and agreed in 1997 to an international phaseout. Because of its importance, many U.S. users have been concerned that existing alternatives to methyl bromide will be less effective and cause financial losses (USDA, 2000).

Phillips et al. (2000) noted that fumigant insecticides are the best tools for quickly reducing insect pest infestations in food processing structures and bulk grain storages, and that methyl bromide is the fumigant of choice in most flour mills and other food processing facilities in North America. Thus, its phase-out is critical in the food processing industry.

Because of concerns that alternatives to methyl bromide for certain applications were unsuitable or not economically feasible, The Report of the Technology and Economic Assessment Panel of the Montreal Protocol allowed for exemptions for use of methyl bromide where, among other criteria, "There are no technically and economically feasible alternatives or substitutes available to the user that are acceptable from the standpoint of environment and health and are suitable to the crops and circumstances of the nomination" (UNEP, 2005).

With few alternatives to MB available, National Pest Management Association (NPMA) has been able to obtain a Critical Use Exemption (CUE) under this provision, permitting its members to use up to a specified amount of methyl bromide each year to treat commodities, and food and feed processing plants. Beginning in 2004, a promising alternative to MB – ProFume® (PF), chemically known as sulfuryl fluoride – was approved by EPA and labeled for use with several cereal grains, dried fruits, and nuts. More recently, it was approved for use on cocoa beans. Although it has similar pest-control capabilities to MB, little independent information has been available to determine whether PF is an economically feasible substitute for MB in food processing facilities and warehouses, and for commodities. The purpose of this analysis was to compare the costs of fumigations using PF and MB, in both food processing facilities and in fumigations of cocoa beans.

2. Materials and methods

Statistical techniques such as econometrics would permit such a comparison if sufficient data with consistent measurements were available. In the short time since approval in 2004, though, the number of firms having used both fumigants is low, and the number of fumigations in which those firms that have used PF is very low and under widely varying conditions, so the usefulness of statistical comparisons is likely quite low.

Thus, an economic-engineering and partial budgeting approach was used, estimating costs using engineering and technical specifications. This approach provides estimates of costs that typical firms would face under typical scenarios, rather than costs particular firms might have experienced under unique situations.

As such, this approach permits comparisons between the two fumigants while holding other factors constant. Within reason, the economic engineering approach should provide useful cost predictions if underlying conditions change, by changing the parameter values used in the calculations. From the perspective of the fumigator, the profitability using either fumigant is Revenue Received from Fumigation minus Cost of Fumigation, where Revenue = Amount received from the fumigation customer (Client), and Cost = Labor Cost + Training Cost + Equipment Cost + Cost of Chemicals Used. It is assumed that a fumigator's revenue will be the same regardless of which chemical is used (this assumption was verified by the fumigator interviews), so the focus here is on costs. Although there may be public relations benefits from using a non-ozone depleting chemical, those benefits would depend on individual firms' marketing efforts.

2.1. Data sources

A potential limitation of an economic-engineering approach is that, because it is based on technical and engineering specifications, it may not reflect realities of use in actual fumigation situations. To provide confidence that the individual cost components reflect the realities of actual fumigations with these products, the economic-engineering estimates were calibrated using several data sources. The most important source was a set of telephone interviews with six fumigators who have used both MB and PF. These hour-long interviews focused on similarities and differences between MB and PF in costs of a typical fumigation. Since, as the fumigators noted, there really is no typical fumigation, a hypothetical fumigation of a 28,317 m^3 food processing/warehouse facility with a fumigant half-loss time of 12 hours was considered. The data determined were: labor needed for a fumigation (setup, fumigation, ventilation, and takedown), wages paid for labor, training needed for workers, differences in dosage and chemical costs, differences in equipment cost and facility preparation, differences in power use, typical pests targeted, and other relevant differences as determined by the fumigators.

A second set of interviews was conducted with wholesale distributors of MB and PF. The primary information obtained from these interviews was the wholesale price differences between MB and PF. The interview data from fumigators and wholesale distributors was supplemented with information from Dow Agrosciences – hereafter Dow – (cost of equipment used for PF, Fumiguide® dosages for PF, and field trial data on amount of PF needed for various fumigations), from National Pest Management Association (recommended dosages for MB and data condensed from several journal articles on efficacy of several fumigants on four stages of various insect species), and from journal articles on the effects of temperature on efficacy of methyl bromide for several species of insects (Vincent et al., 1980; Bell, 1988). Table 1 shows the parameters used in the core model. These parameter values reflect industry data at the time of this study. Changes in the industry or economy, including changes in underlying industry structure or changes in regulations or their interpretation, would likely affect these values.

Table 1 Parameters used to calculate costs of fumigating a 28,317 m^3 food processing facility using methyl bromide (MB) or ProFume (PF). Values in USA $.

Parameter	MB	PF
Labor Rates ($/hr)		
Setup	$18	$18
Supervisory	$50	$50
Fumigation	$18	$18
Aeration	$18	$15
Overtime	$28	$28
Hours/Worker		
Setup	5	5
Supervisory	15	15
Fumigation	24	24
Aeration	12	8
Overtime	20	16
# Workers		

Parameter	MB	PF
Setup	4	4
Supervisory	1	1
Fumigation	4	4
Aeration	3	3
Overtime	1	1
Worker Training		
hours per worker per year	5	5
yearly fee per worker	$150	$150
Interest Rate	**10%**	**10%**
Temperature (C)	29.4	29.4
Half-Loss Time (hrs)	12	12
Building Size (m^3)	28317	28317
Equipment Life (yrs)	4	4
Purchase Prices ($)		
Fumiscope	$1333	$1333
Interscan/electronic monitor	$1000	$3559
Draeger Tube Monitor	$215	$0
Heavy-duty hoses, fittings	$1500	$2480
monitoring hoses	$475	$475
high-capacity fans ($100/fan * 13 fans)	$1300	$1,300
Present Value Factor (PVIFA)	3.170	3.170
Cost of Fumigant ($/kg)	$15.00	$11 - $15
Fumigant Dose (g/m^3)	16, 24, 32	Fumiguide low (26), high (50); 40
Equivalent fumigations per year	50	50

2.2. Labor cost

Labor used in a fumigation includes a survey or analysis (screening) of the fumigation site (typically by a supervisor), then preparation of the facility by workers (including thorough sealing of vents and other openings; according to firms interviewed, this often can be done while the plant or warehouse is in operation), the actual fumigation, ventilation of the facility after fumigation, and removal of temporary sealing materials.

All of the fumigators surveyed indicated that these job components differed very little between the two fumigants. Some indicated that if there were any differences, PF required more attention to sealing because "…it is more volatile than MB" (technically, it has lower specific gravity (Thoms et al., 1990) and has a higher vapor pressure). In addition, they indicated that PF might require more setup time because hoses are inserted into the facility from outside, whereas MB tanks are brought into the facility itself. However, Thoms et al. (1990) note that methyl bromide can be introduced into a structure from the outside, and one of the fumigators interviewed reported capability of doing that.

On the other hand, the additional time and effort required for PF at these stages might be offset by reduced time needed for takedown (since PF tanks are already outside the facility and don't need to be taken out of the building). The similarity between MB and PF fumigations in these kinds of costs is supported by the reported experiences of Subramanyam (2006). Also, because PF has higher vapor pressure and lower sorption, most of the fumigators reported that aeration of the facility after fumigation would take less time.

Labor cost is specified as [(setup labor hours/worker x number of setup workers x operating wage rate) + (supervisory labor hours/worker x number of supervisors x supervisory wage rate) + (fumigation labor hours/worker x number of fumigation workers x fumigation wage rate) + (aeration labor hours/worker x number of aeration workers x aeration wage rate)]. If any of these workers must work more than eight hours per day, they are assumed to receive time-and-a-half pay for those hours.

2.3. Training cost

Training cost is specified as a combination of an annual training fee (assumed to be $150/worker) plus an hourly charge for each worker equal to his/her hourly wage rate x number of hours of training required per year (assumed to be five hours per worker). The total training cost for all workers is divided by the number of fumigation jobs per year (assumed to be 50) to express the training cost as training cost/job.

2.4. Equipment cost

There are some differences in equipment cost between MB and PF because PF requires more specialized equipment. Typically, a computer is needed to calculate dosage of PF using the Fumiguide®. Strong-walled hoses are needed to introduce PF into the facility. During fumigation, concentration of PF and MB is typically measured using a Fumiscope or similar device, and a device such as Interscan (PF) or color diffusion tube-type monitor (MB) is used to measure whether fumigant concentrations have decreased sufficiently to permit safe re-entry of the facility after ventilation. Since a tube-type monitor is the only approved device for determining re-entry clearance after a MB fumigation (Degesch America), the amortized cost of a tube-type monitor as well as the cost of two tubes at 12 USA$ per tube (assuming one test in each of two locations) is included for MB.

Each piece of equipment is amortized over its expected useful life using the formula Equipment Cost = [purchase cost of equipment]/$PVIFA_{ni}$, where $PVIFA_{ni}$ denotes present value interest factor for an annuity of n years at i percent interest. $PVIFA_{ni} = [1 - (1/(1 + i))^n]/i$, where n is the usable life of the machine and i is the interest rate on the loan. Dividing by $PVIFA$ allocates the investment cost, including interest cost, equally over each year of the equipment's useful life. The yearly equipment cost is divided by the number of fumigations per year to express equipment cost as equipment cost per fumigation.

2.5. Cost of chemicals used

Cost of chemicals used appears to be the main factor affecting fumigation cost differences, according to the interviewed firms. Chemical cost is measured for each chemical as dosage in g/m^3 x 1,000 x cost (USA$/kg) x 28,317 m^3. PF's Fumiguide has three choices for fumigators: a high dose, which should be nearly 100% effective for all stages (eggs, larvae, pupae, and adults) of the insect species for which it is approved for use, a user-defined rate, and Fumiguide's low dose, which should be effective for all post-embryonic stages and 50% effective for the egg stage of most species. MB is efficacious for most insects at all life stages at the recommended doses.

Dosage rates for MB are taken from reported experiences of the fumigators interviewed, as well as from label rates and other data sources. Dosage rates for MB are assumed to apply for temperatures from 21.1 - 37.8°C. The label rate for MB is 16 g/m^3 for processed food (up to 48 g/m^3 for spices and herbs, and 64 g/m^3 for dried peas). Half of the fumigators interviewed reported using 24 or 32 g/m^3 for a 24-hour exposure time, and half of the fumigators reported that their standard rate for MB was 16 g/m^3. This was especially true if they had previously fumigated a particular facility and repaired any leaks, or if they had monitored the concentration-time (CT) product and found that a lower dose provided effective exposure of insects to the fumigant. There is also a possibility that a fumigator may need to use a higher rate of MB.

In addition, Dow conducted 96 fumigations at food processing facilities and warehouses. Their average dosage for these facilities was 40 g PF/m^3, suggesting that as fumigators gain experience with PF, they may find that they will be able to reduce dosage from the Fumiguide recommendations, adapting it to specific facilities just as they have with MB. Although it is included here for comparison purposes, none of the fumigators interviewed used the low dose for fumigating processed food. Since the low dose is not sufficient to kill all eggs of some insect species (particularly red flour beetle, a typical pest reported by the fumigators), they reported concerns about the potential for insect population rebound and dissatisfied customers. However, Subramanyam (2006) reported effective fumigations using PF's low dose. He noted, though, that in two of three mills, insect populations reached pretreatment levels after two months, and that further research was needed to determine the reason for this population rebound (Subramanyam, personal communication). Here, the dosage of MB is varied from 16 g/m^3 to 32 g/m^3, and the dosage of PF is varied from Fumiguide's low dose to Fumiguide's high dose.

Fumigators and distributors reported that differences in price they paid for MB and PF ranged from zero (no difference) to PF 4.41 USA$/kg less expensive than MB. Because the number of observations is small, and the range of reported values is large, presenting the results based on the range of price/quantity observations rather than on an average of them provides greater confidence in the results. Thus, the wholesale cost of MB is set at 15.43 USA$/kg, and the wholesale cost of PF is varied from 11.02 USA$/kg to 15.43 USA$/kg (a relative difference of 0 USA$ to 4.41 USA$/kg, consistent with the range reported by fumigators and wholesalers).

3. Results

3.1. Labor and training costs

Labor costs for a hypothetical fumigation with each fumigant are shown in Table 2. The only difference between MB and PF is a reduced labor cost for ventilation for PF because its greater vapor pressure and lower sorption likely permits faster aeration of the facility after fumigation.

Table 2 Equipment cost per year and total per job for methyl bromide and ProFume fumigation. Values in USA$.

Amortized Equipment Cost per yr.	Methyl Bromide	ProFume
Fumiscope	$421	$421
Interscan/electronic monitor	$315	$1123
hoses	$473	$782
monitor hoses	$150	$150
tube-type monitor	$68	$0
monitor tubes ($24/job x 50 jobs)	$1200	$0
Fans	$410	$410
Total per job (50 jobs/yr)	$61	$58

3.2. Equipment costs

Equipment costs for each fumigant using the parameters specified in Table 1 are shown in Table 3, which reports the costs on a yearly basis and as cost per job, assuming 50 fumigations jobs per year.

Table 3 Labor cost per (hypothetical) fumigating job for methyl bromide and Profume. Values in USA$.

Labor Cost per job	Methyl Bromide	ProFume
Setup	$360	$360
Supervisory	$750	$750
Fumigating	$1728	$1728
Ventilation	$648	$432
Overtime	$864	$864
Total	$4350	$4134

3.3. Cost of chemicals used

These results indicate that PF has a very slight advantage in equipment cost, and a somewhat larger, though still small, advantage in labor cost. However, the cost of fumigant used in a typical fumigation is higher for PF than for MB for most scenarios. Although the price per kg of PF is the same or lower than that for MB, a greater quantity of fumigant is typically used for a PF fumigation than for a MB fumigation. Although the fumigating companies were not asked about profitability, one of them noted that because more PF fumigant is used in a typical fumigation, its revenues (and profits) are higher fumigating with PF than with MB. The markup it charges clients is the same for each chemical, but since the quantity of PF used is higher, the extra revenue received is correspondingly higher. The flip side, of course, is that the client faces higher costs.

3.4. Total fumigation costs

To show the fumigation costs under various combinations of fumigation dosage and fumigant price, Table 4 is arranged so that from left to right the dosage of MB varies from 16 g/m^3 to 24 g/m^3 to 32 g/m^3, and the dosage of PF varies from Fumiguide's low dose to Dow Agroscience's average field test dose of 40 g/m^3 to Fumiguide's high dose, while from top to bottom, the price of PF is varied.

Table 4 Cost of hypothetical 24-h fumigations of a 28,317 m^3 food processing facility for methyl bromide and ProFume. Values in USA$.

			Cost per Job ($)					
Cost MB/Kg ($)	**Cost PF/Kg ($)**	**Item**	**Methyl Bromide (16 g/m^3)**	**Methyl Bromide (24 g/m^3)**	**Methyl Bromide (32 g/m^3)**	**(low ProFume dose 26 g/m^3)**	**(ProFume Dow average - 40 g/m^3)**	**ProFume (high dose 50 g/m^3)**
15.34	15.34	Equipment	61	61	61	58	58	58
		Labor	4350	4350	4350	4134	4134	4134
		Training	19	19	19	19	19	19
		Fumigant	7000	10500	14000	11452	17500	22008
		Total Cost	11430	14930	18430	15663	21711	26219
15.43	13.22	Equipment	61	61	61	58	58	58
		Labor	4350	4350	4350	4134	4134	4134
		Training	19	19	19	19	19	19
		Fumigant	7000	10500	14000	9816	15000	18864
		Total Cost	11430	14930	18430	14027	19211	23075
15.43	11.02	Equipment	61	61	61	58	58	58
		Labor	4350	4350	4350	4134	4134	4134
		Training	19	19	19	19	19	19
		Fumigant	7000	10500	14000	8180	12500	15720
		Total Cost	11430	14930	18430	12391	16711	19931

For example, when PF costs 11.02 USA$/kg (4.41 USA$/kg less than MB), the dosage rate for MB is 24 g/m^3, and the dosage rate for PF is the Fumiguide® high dose, then the total fumigation cost for PF is 19,931 USA$. This is 33% higher than the 14,930 USA$ cost of a MB fumigation. The difference is smaller if the dosage rate of PF is lower. In the example above, when the dosage rate for PF is reduced to 40 g/m^3 (the Dow experiments' average), the cost of a PF fumigation is 16,711 USA$. This is 12% higher than the 14,930 USA$ cost of a MB fumigation. Table 5 shows these percentage differences.

Table 5 Percent by which ProFume fumigation cost exceeds methyl bromide fumigation cost for a 28,317 m^3 food processing facility*. Values in USA$.

		% by which PF fumigation cost exceeds MB fumigation cost		
Cost PF/Kg ($)	**MB (g/m^3)**	**26 ProFume (low dose g/m^3)**	**ProFume (Dow average - 40 g/m^3)**	**ProFume (high dose 50 g/m^3)**
15.43	16	37	90	129
	24	5	45	75
	32	-15	18	42
13.22	16	23	68	102
	24	-6	29	55
	32	-24	4	25
11.02	16	8	46	74
	24	-17	12	33
	32	-33	-9	8

*Negative numbers indicate that MB cost exceeds PF cost.

Conversely, the difference is larger if the relative cost of PF fumigant is higher or if the dosage rate of MB is lower. For example, if the cost of PF is only 2.20 USA$/kg less than the cost of MB, the dosage rate of MB is 24 g/m^3, and the dosage rate of PF is 40 g/m^3, the total cost of a PF fumigation is 19,211 USA$ and the cost of a MB fumigation is 14,930 USA$, so that the cost of a PF fumigation is 29% higher than that of a MB fumigation. If the dosage rate of MB is lowered to 16 g/m^3 (while holding other values the same), the cost of a MB fumigation drops to 11,430 USA$ and the cost of a PF fumigation is 68% higher than the cost of a MB fumigation. (These parameter values are consistent with those fumigators who reported using 16 g/m^3 for a MB fumigation and Fumiguide's high dose for a PF fumigation).

3.5. Fumigation of cocoa beans

The fumigators reported very little difference between MB and PF in labor cost and equipment cost, so those parts of the economic-engineering model are transferred directly from the previous section, assuming fumigation jobs comparable in size to that assumed in the previous section. However, fumigation of cocoa beans requires a lower dosage of ProFume than fumigation of food processing facilities because cocoa bean fumigation is commodity fumigation rather than space fumigation, and the commodity is taking up a larger proportion of the fumigated space.

The fumigators interviewed reported successful fumigation with 16 g/m^3 of MB, and 24 g/m^3 of PF, a dose which was recommended by Dow representatives for application to cocoa beans. Table 6 shows the cost of fumigating cocoa beans using these doses. When the two fumigants cost the same per kilogram, a PF fumigation costs about 29% more. When the costs differ by 2.20 USA $/kg, a PF fumigation costs 16% more, and when the cost difference is $4.40/kg, a PF fumigation costs 2% more.

Table 6 Cost of hypothetical 24-h fumigation for cocoa beans (MB dose at 16 g/m^3 and PF at 24 g/m^3). Values in USA$.

		Cost per job ($)						
MB dose (g/m^3)	**Item**	**Methyl Bromide @$15.43/kg**	**ProFume @$15.43/kg**	**% Diff.**	**ProFume @$13.03/kg**	**% Diff.**	**ProFume @$11.03/kg**	**% Diff.**
16	Equipment	61	58		58		58	
	Labor	4350	4134		4134		4134	
	Training	19	19		$19		19	
	Fumigant	7000	10500		9000		7500	
	Total Cost	11430	14711	29%	13211	16%	11711	2%
24	Equipment	61	58		58		58	
	Labor	4350	4134		4134		4134	
	Training	19	19		19		19	
	Fumigant	10500	10500		9000		7500	
	Total Cost	14930	14711	-1%	13211	-12%	11711	-22%

*Negative numbers indicate that MB cost exceeds PF cost.

However, if the dose used for MB is 24 g/m^3, the rate specified in the National Pest Management Association's application for Critical Use Exemption – the label for MB specifies a rate ranging from 1 - 2 lbs/1,000 ft^3 (16-32 g/m^3) for cocoa beans using a 16-24 h exposure, Table 6 shows that when the two fumigants cost the same per pound, a PF fumigation costs about 1% less. When fumigant costs differ by 2.20 USA$/kg, a PF fumigation costs 12% less, and when the cost difference is 4.40 USA$/kg, a PF fumigation costs 22% less. The key reason for PF being relatively more attractive economically for cocoa beans than for food processing facilities, compared to MB, is because the amount of PF needed for cocoa beans is substantially lower.

4. Discussion

The most important factor affecting relative profitability of the two fumigants is amount of PF required for effective fumigation relative to amount of MB required. Under typical assumptions and parameter values, a PF fumigation uses about two thirds more fumigant than MB. , Even though unit price of PF is

typically less than price of MB, a fumigation of a 28,317 m^3 warehouse using PF is 28% to 55% more expensive than the same fumigation using MB. The difference is less if the price of PF is reduced relative to the price of MB, or if dosage rate of PF can be reduced. PF can be less expensive than MB, however, for fumigating cocoa beans because the amount of PF needed for cocoa beans is substantially lower.

Acknowledgements

Financial support by National Pest Management Association and Dow AgroSciences, and comments by Gene Harrington, Dan Jenkins, Tom Phillips, and Surresh Prabhakaran, are gratefully acknowledged. Any remaining errors are the responsibility of the authors.

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