Evaluation of Alternatives to Methyl Bromide for Use in Structural Fumigation of Canadian Pasta Manufacturing Facilities 2007/2008

A Report to Agriculture and Agri-Food Canada

Prepared By

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Executive Summary

This report presents the operational assessment and efficacy assessment of trial fumigations conducted in three Canadian pasta manufacturing facilities conducted in 2007 and 2008 using the fumigant ProFume (sulfuryl fluoride or SF) an alternative to methyl bromide (MB).

Methyl bromide has been the preferred chemical fumigant used in the fumigation of wheat flour/semolina mills and pasta facilities in Canada for several decades. Under the provisions of Canada's federal Ozone-Depleting Substances (ODS) Regulations, MB is no longer permitted for use in structural fumigation unless under permits issued by Environment Canada under either a Critical Use Exemption process or Emergency Use Exemption process. Use of MB in the participating pasta facilities under CUE permits in 2006, 2007 and 2008 has allowed for some limited comparative analysis of efficacy of SF as compared with MB in these 3 pasta facilities.

Under this project, 3 trial SF fumigations were conducted. One was a trial of a very limited area of a facility (semolina receiving, storage and reprocessing section). A trial at the second facility encompassed an entire production line area of significant volume conducted in tandem with a MB fumigation of a small reprocessing room in another area of the same plant plus a fogging of a warehouse area. The third trial was a whole-facility trial using SF. The first two trials were undertaken in October of 2007 and the third trial was completed in summer of 2008.

From an operational perspective, the participating firms found that fumigations conducted with SF are comparable to MB. The plant preparation steps and time required are quite comparable. The duration of the fumigations are also comparable. The re-start of processing activities was comparable in terms of scheduling and trouble-shooting.

From a cost perspective, the participating firms found that the staff time and related costs were comparable. However, the combined cost of services and SF gas provided by pest control service providers was significantly higher than MB fumigations conducted at two of the three facilities in recent years (2006 to 2008). The small scale (part facility) of the third trial did not permit a meaningful cost comparison as this firm has normally conducted a whole plant (production and warehouse) MB fumigation in recent years.

From an efficacy perspective, SF was found to kill all adult insects placed in test vials (bioassays) in the plants in each trail in the areas fumigated. However, insect egg mortality in bioassays ranged from 69 to 81% as compared to 100% in comparable MB fumigations. In addition, insect populations in 2 of the 3 trials that were observed in dome trapping reached pre-fumigation levels within 12 to 14 weeks of SF fumigation. In the opinion of the participating firms and CPMA, this calls into question the value of SF as a substitute for MB, considering the cost per fumigation and the implied need for at least two fumigations annually.

As noted in Appendix 1, the participating firms opted to not conduct follow-up fumigations with MB in the same year as SF trials. Participating firms advised that this was due to cost and scheduling constraints that did not allow them to conduct fumigations as a corrective measure for lack of efficacy of the SF trials.

Readers should also note that the SF trials were not able to be conducted under exactly the same procedures as MB fumigations as a consequence of the only partial registration of SF (contact with semolina and pasta not permitted under label use approved as of 2007 and 2008. At time of writing

of this report, full registration of SF by Canada's Pest Management Regulatory Agency is still pending but expected in 2009.

1. Introduction – Project Context and Objectives

The context and objectives for the MB alternative trials conducted with the support of funding provided under an ACAAF contribution agreement with Agriculture and Agri-Food Canada (AAFC) are explained in the February, 2008 interim report to AAFC attached to this report as Appendix 2. Also included in the 2008 interim report is some general information on pest control challenges in pasta manufacturing facilities and case studies for two of the three trials conducted under this initiative. Readers of this report are encouraged to refer to Appendix 2 for additional detail.

Readers of this report should note, however, that reduced quantities of MB available to Canadian pasta firms under Critical Use Exemptions continue to present operational challenges to the industry. Customer and regulator expectations for stored product pest control have not been relaxed. On the contrary, customer and regulatory food safety vigilance has intensified in 2007 and 2008. This is being reflected in the third party food safety audit criteria that have become more stringent in 2008 in particular.

This is to say that the importance of finding and proving out the commercial (technical and cost) feasibility of reliable and efficacious alternatives to MB has, if anything, increased. It is in this context that the qualified success (less than optimal mortality) of SF trials conducted under this initiative represents a significant disappointment to the industry and CPMA.

Highlights of the findings of the first two trials (case studies 1 and 2) are included below. Full texts are in Appendix 2.

The brief but complete case study of trial 3 is included below.

2. Plant 1: Operational Assessment of SF Fumigation 2007

<u>Lessons Learned</u>

Logistics

- Plant preparation for fumigation of the production areas with SF was very similar in terms of time, labour and total costs to typical MB fumigations. Apart from requiring that all semolina, finished pasta and regrind pasta be removed, the preparation required was equivalent.
- Set-up of gas injection equipment and monitoring lines, plus staging of gas cylinders, manifold and monitoring equipment was accomplished within a reasonable time frame of less than 6 hours.
- Staging of the equipment and injection of the gas from a point exterior to the building was seen as an advantage from a worker safety perspective.
- The gas-tightness that had been observed in past MB fumigations was sufficient to conduct the SF fumigation largely as planned.

Efficacy

- Assay vials retrieved from the plant indicated that a number of vials had survival of eggs.
- Early observations (6 to 8 weeks) indicated that population rebound was being experienced sooner than would have been the case for a typical MB fumigation. There is some concern that this is as a result of the regrind totes not being able to be fumigated but there is no hard evidence to identify this as a source of re-infestation.
- Results of pheromone trap data (20 weeks) were not available at time of drafting the document. Post treatment monitoring was continued for only 15 weeks. However, adults captured in dome traps reached pre-fumigation levels by week 12 to 14.
- There may be a need to increase SF concentrations in future fumigations to achieve a higher level of egg stage mortality. Addition of heat (using comfort heating equipment and/or dryers) may also be considered to improve efficacy.

Affordability

The cost of the SF fumigation was roughly 175% the estimated cost in 2007 for a comparable MB fumigation of the same production areas of the building.

3. Plant 2: Operational Assessment of SF Fumigation 2007

Lessons Learned

Logistics

- Plant preparation for this part-facility fumigation of semolina storage and regrind areas with SF was very similar in terms of time, labour and total costs to typical MB fumigations. Apart from requiring that all semolina, finished pasta and regrind pasta be removed, the preparation required was equivalent.
- Set-up of gas injection equipment and monitoring lines, plus staging of gas cylinders, manifold and monitoring equipment was accomplished within a reasonable time frame.
- The very small area (and volume) of the portion of the plant fumigated required very small quantities of SF gas.
- The acceptable gas-tightness that had been observed in past MB fumigations of the whole plant including the production area was not found to exist for the small area to be fumigated (semolina room).
- In the absence of being able to somehow permanently or temporarily seal off the semolina room from the other areas of the plant, it would appear that chemical fumigations of the semolina room alone will not be feasible.
- This suggests that the only means of control measures using chemical fumigants will be whole facility fumigations, regardless of cost implications or actual need in other areas of the plant.

- The company is still considering heat treatment as an alternative to chemical fumigation for an additional trial treatment of the semolina room. There remain concerns about sensitivity of equipment that are being fully examined before a decision can be taken on a heat treatment trial.

Efficacy

- Assay vials retrieved from the plant indicated that a number of vials had survival of eggs.
- Efficacy (mortality) of indigenous insects (those not imported in the assay vials) was really not possible to assess since pre-treatment monitoring and pheromone trap counts over the prior several months did not indicate an infestation of any of bins, transfer or regrind equipment prior to the treatment.
- Early observations (6 to 8 weeks) post-treatment did not indicate presence of insect pests in the treated area of the plant or other areas.

Affordability

Had the area fumigated proven to be sufficiently gas-tight, fumigation with SF as an alternative to MB would have been considered an affordable alternative for the semolina storage and regrind area of the plant.

However, since SF use would dictate a whole facility fumigation, there would be a significant cost increase (gas prices predominantly) over historical whole facility fumigation costs using MB.

4. Plant 3: Operational Assessment of SF Fumigation 2008

Facility Description

This pasta manufacturing plant is housed within a large building of approximately 150,000 square feet in floor area. The building was not designed and built to be a pasta manufacturing facility. Rather, the structure was modified and adapted for its current use. The building is located in a light/moderate industrial area within 40 metres of other buildings.

The facility houses bulk raw material (durum wheat semolina) receiving and storage, packaging materials receiving and storage, pasta production lines, short term finished product warehousing, a mechanical maintenance shop, QA lab and offices. Finished product is usually shipped to a separate warehouse/distribution centre within 24 hours of coming off production lines. As a consequence, except for the semolina silos, the entire plant can be easily emptied of foodstuffs before fumigation. This is not typical of Canadian pasta plants that normally have significant inventories of finished product in a warehouse area that is contained within the same structure as the production area.

The other aspect of the plant that is not typical is that the production area of the plant is almost completely divided by a masonry wall into two sections that each contain production lines. One of the sections holds production lines, warehouse and regrind equipment within the same space. The same section of the plant houses a very large volume of packaging materials, much of which would not be able to be left in the building if a heat treatment were attempted.

While in theory this division of space might facilitate treatment of part of the plant with methyl bromide (MB) alternatives, this has never been attempted. In all past MB fumigations, the entire plant has been treated, including the semolina storage area.

The concrete floor of the facility is in excellent condition. The structural gaps between floor sections are well sealed. Other than dividing walls for offices, labs, electrical and other special purpose rooms, the building has only one masonry partitioning wall, as noted above. The exterior walls are predominantly insulated metal cladding. The ceiling is very high, resulting in the building being a very large volume (gas) rectangular structure.

What is typical of pasta facilities is a large number of production lines to accommodate the manufacture of a wide range of pasta goods. The majority of the production equipment is elevated above the floor, facilitating an aggressive, continuous cleaning program.

This facility is also typical of most food processing facilities in that it normally operates 24 hours per day, 7 days per week As a consequence, the shut-down time associated with pest control treatments is sought to be as brief as possible while achieving the desired interruption in the insect pest life cycle. This has historically been a total of 3 consecutive days only for one MB fumigation annually.

Recent Pest Control Program

This facility relies primarily upon a continuous structure and production equipment cleaning and maintenance program and has been fumigated once annually during summer months, using MB. Summer scheduling has optimized the efficacy of insect population control using a single annual fumigation. Each fumigation in the past has been the entire building, including the warehouse area.

The company engaged its pest control service provider to conduct an ongoing program of insect population monitoring using pheromone traps. This was initiated approximately 6 weeks prior to the SF trial conducted in summer of 2008 and continued for 20 weeks following.

The preparation for a methyl bromide fumigation has typically been:

- The fumigation is usually scheduled to coincide with a statutory holiday weekend to provide the necessary 3-day shutdown period.

- The very high level of plant cleaning (equipment and structure) in this operation allows for normal operation through virtually the entire production week leading up to the fumigation. However, some production lines are usually shut down for cleaning and partial disassembly approximately 24 to 36 hours in advance of gas injection. Final shutdown of all production and packaging lines usually occurs less than 12 hours before gas injection.

- Pest control service providers usually undertake sealing (polyethylene film, etc.) of doors and ventilation ports in the same sequence as production equipment shutdown over a period of about 24 to 30 hours.

- Despite the sealing that has been undertaken for past fumigations, the building had not been observed to be as gas-tight as thought to be ideal for SF treatment.

2008 Trial SF Fumigation

The trial fumigation with SF was conducted in this facility in mid-summer of 2008. The plant preparation was essentially as per the steps outlined above for a typical MB fumigation. The shutdown sequence began on the Friday of the July 1 long weekend, as had taken place the previous year for the MB fumigation.

However, the requirement to avoid SF contact with food made it necessary for staff to empty the semolina silos, adding significantly to preparation time and labour cost. Despite this, gas injection began on Saturday as planned. The facility exhibited excellent gas-tightness/half-loss time higher than anticipated, attributed to calm wind conditions.

Pest control service provider staff were able to enter the plant by the Sunday morning. The plant was declared safe for staff to enter in advance of the expected time. Administrative, maintenance and supervisory staff were able to enter the plant by late Sunday. Manufacturing operations resumed as planned on the following Tuesday.

In summary, SF trial fumigation was executed as expected, with no major unexpected constraints, rendering the trial essentially equivalent to a MB fumigation from the perspective of staff human resource requirements and lost manufacturing time.

Dr. Paul Fields of AAFC's Cereal Research Centre) placed vials of insects at various positions throughout the structure as a means of measuring the rate of insect mortality achieved via the fumigation. Adult insect mortality was 100%. Immature insect mortality in the bioassays was observed to be 94% as compared to 100% in the 2007 MB fumigation.

Lessons Learned

Logistics

- Plant preparation for fumigation of the production areas with SF was significantly greater than for MB in terms of time, labour and total costs. Additional sealing was required to improve gas retention. Requiring that all semolina, finished pasta and regrind pasta be removed from the plant added considerable labour time and cost.
- Set-up of gas injection equipment and monitoring lines, plus staging of gas cylinders, manifold and monitoring equipment was accomplished within a reasonable time frame as planned.
- The gas-tightness that had been observed in past MB fumigations was less than indicated by the longer half-loss time achieved in the 2008 SF trial. Conditions (temperature and wind) were favourable on the day of the SF fumigation.
- Total elapsed time required for a whole-facility fumigation with SF 3-day long weekend from shut-down to start-up) was no greater than had been required for the previous MB fumigation conducted at end of June, 2007.

Efficacy

- The 94% mortality rate of immature insects in the bioassays was a disappointment, considering the success of the trial from a logistical and total elapsed time perspective.

- Visual observations led staff to believe the fumigation was highly successful in the early weeks following the SF fumigation. However, adult insect counts in dome traps were roughly equivalent to pre-fumigation levels 12 weeks after the fumigation.

Please refer to ***Appendix 1: Interim Efficacy Assessment Report on Methyl Bromide Alternatives in Canadian Pasta Production Facilities, February 2009*** for more detail on observed mortality and post-treatment monitoring.

Affordability

As noted earlier, this is a large facility. The cost of the SF trial in 2008 was approximately 150% of the cost for the comparable MB conducted in 2007. Considering the SF fumigation achieved significant reductions in insect numbers for less than 4 months, two SF fumigations per year may be required to achieve adequate control in this facility. That would triple the cost of the fumigation component of the plant's pest control program as compared to MB.

Consideration of Other Alternatives to MB

In light of the experience gained with the 2008 SF trial that demonstrated operational feasibility within the time frame required, the company is considering conducting a second SF trial in 2010 on the assumption that full registration is completed. Plans are already in place for a MB fumigation in 2009.

The company has investigated acquisition of heat treatment equipment to permit conduct of heat treatments at the company's short term discretion using company personnel. This would provide additional flexibility and choice as to when and how many to conduct to complement other IPM components. However the acquisition cost of the equipment exceeds the company's current means in the economic conditions that have faced the industry between mid-2007 and early 2009.

5. Highlights of Efficacy Experienced With SF

An examination of the efficacy experienced in the 3 SF trials is provided in Appendix 1 to this report. This is an updated report prepared by Dr. Paul Fields of AAFC who assisted the participating firms and pest control service providers in assessing efficacy through placement of vials of living insects and incubation of the vials following the treatments to observe apparent hatching of eggs and maturing of pre-adult life stages under controlled laboratory conditions (AAFC's Cereal Research Centre in Winnipeg, MB) in the weeks following fumigation.

Dr. Fields reported that all 3 SF trials achieved 100% mortality of adult insects counted in all bioassay vials. This is comparable to results achieved in prior MB fumigations in these and other (flour milling) facilities.

However, Dr. Fields also reported survival of immature insects ranging from 69 to 81%.

This survival rate was a disappointment for participating firms who had expected mortality rates comparable to that experienced historically with MB.

Also of concern was the relatively short 12 to 14 week adult population rebound to pre-SF fumigation levels observed in case studies (plants) 1 and 3.

6. Outlook for Adoption of Other MB Alternatives

Heat Treatment

All three firms participating in this project have consulted with heat treatment service providers and/or original equipment suppliers. None of the three companies have been able to receive assurances that heat treatment at usual temperatures targeted (50 degrees C.) will not result in damage to electronic or other equipment.

Despite this, one firm that holds the greatest degree of concern about possible equipment damage (plant 3) has costed the acquisition of equipment to enable the firm to conduct in-house (with company labour) heat treatments. However, in the current (2009) economic circumstances, in the wake of the highest and most volatile raw material (durum wheat and semolina) costs in history (2007/2008 crop year), acquisition of the heat treatment equipment is not presently an option.

A second firm (plant 2) is considering the possibility of conducting a heat treatment or SF fumigation in 2010 in part of the plant (warehouse or production area, to be determined) to compensate for the significantly insufficient amount of MB available under CUE.

The third plant (plant 1) is concerned about possible equipment damage and the anticipated very high cost of heat treatment associated with treatment of the very large and irregularly configured facility. That firm does believe, however, that one area of limited size might be well suited to heat treatment and a possible trial in late 2009 or 2010 in conjunction with a fumigation of the production and warehouse areas of the plant.

Heat, Carbon Dioxide and Phosphine in Combination

Despite the apparent feasibility of this method (two successful fumigations in Canadian flour mills to date), and full registration, the technology holder and service provider having the experience has not contacted any of the pasta firms participating in this initiative to propose a trial. One reason might be that the firms conducting the trial have not published the findings for internal reasons.

CPMA members have been advised of this situation and may pursue information in coming months.

Integrated Pest Management Alone

None of the participating firms have seriously considered the option of attempting to achieve a satisfactory level of insect pest control without the use of annual fumigations in their respective programs. However, the reality is that were it not for the IPM components in use, including stepped up measures (periodic fogging) adopted in one of the plants to compensate for poor SF efficacy, two of the three firms (plants 1 and 3) would not have achieved satisfactory control in 2008.

As noted in the case study and appended efficacy report for plant 2, that firm is fortunate to have experienced a satisfactory degree of control in 2008 (some insects present but not at levels considered to be out of control) as a consequence its IPM activities.

7. Importance of Emergency Use of MB – Canada's ODS Regulations and Use Permit System

CPMA acknowledges with respect and appreciation the efforts of Environment Canada to amend the ODS Regulations to make them as enabling as possible in terms of supporting experimental use of MB alternatives while also providing a safety net in the form of emergency use applications. Provided that MB is commercially available for other uses (other than structural use) in North America, the more recent provisions of the ODS Regulations will be of great value in coming years.

CPMA members are disappointed that the CPMA's critical use exemption reapplications have been met with such a degree of criticism and skepticism on the part of MBTOC (Methyl Bromide Technical Options Committee) of the Montreal Protocol. This continues to be true in 2009 as reflected in the observations and questions presented to Environment Canada in February of 2009 by MBTOC to be forwarded to CPMA in regard to the 2010 CUE nomination.

While CPMA has done its best to respond to MBTOC in a responsible fashion, incorporating the information that is contained within this report, CPMA sees it unlikely that the CUE process will meet CPMA member real needs for MB in 2010 and 2011. At the MB level nominated for 2010, no single CPMA member firm will have an adequate volume of MB to conduct a proper fumigation. As a consequence, the three firms participating in the trials described in this report will have to make use of the import and use transfer provisions that have been incorporated into the ODS Regulations. If the transfers are applied for and administered in a timely fashion, at least one of the three firms and possible two will have no option in 2010 but to use a MB alternative fumigant or heat treatment. Put in other terms, the regulated reduction in MB supplies is working as intended. **CPMA wishes readers to note that the Canadian pasta industry is of the view that it would be reasonable to provide the industry with additional time to adjust and that CUE's remain appropriate.**

An additional factor that the industry is contending with is that technology holders and pest control service providers are not really motivated in a commercial sense to invest in demonstration projects for the pasta industry's evaluation. The fact is that pest control in pasta facilities in Canada is a very small niche market, representing a very small portion of Canadian demand for services. The pasta industry is not witnessing a great deal of eagerness and competition among service providers to meet the industry's real need to compensate for loss of MB as the preferred means of control demonstrated to be effective. MB is effective, demonstrated by many years of industry experience and the MB fumigations documented in the appendices to this report.

In this context, CPMA wishes to note that there is a significant probability that its member firms will encounter levels of infestation in future, despite all IPM efforts and use of MB alternatives, that will cause member firms to seek emergency importation and use permits under Canada's ODS Regulations. When such a situation arises, the industry will need the capacity within the regulator (Environment Canada) to respond in the very short time contemplated in the drafting of the emergency use regulatory provisions and evaluation process foreseen. That capacity to administer an emergency use application must remain in place until such time as the possible need for MB for emergency use is demonstrated to no longer exist.

For access to MB to no longer be a requirement, the conditions outlined in Canada's National Management Strategy will have to be met. In CPMA's view, these conditions have not been met.

CPMA also notes that the business climate that existed for the Canadian pasta industry when the National Management Strategy was drafted has already changed substantially. The industry is facing even greater levels of scrutiny from customers (further processors, foodservice organizations, distributors and retailers) whose expectations of food safety assurance have risen significantly. The unintended presence of chemical substances (unsafe substances deliberately added by offshore ingredient manufacturers like melamine) and bacterial organisms experienced in other North American food industry sub-sectors in 2008 (Listeriosis) have triggered a new level of scrutiny. The food and beverage sector is being driven toward a “zero tolerance” target by changing societal expectations. These pressures are already being felt by CPMA members in the first quarter of 2009.

Both the Canadian Food Inspection Agency and the U.S. Food and Drug Administration are being called upon by their respective elected levels of government to increase vigilance. These pressures will also be reflected in new provisions in third party food safety audit requirements for pasta plants and other cereal grain processing establishments. Tolerances for live insect pests in facilities and insect fragments in foodstuffs can be expected to disappear. This evolving situation changes the “food safety” implications of MB phase-out, whether or not there is historical evidence that a food safety risk is actually presented by stored product pests.

Accordingly, CPMA will look to the support of Environment Canada and Agriculture and Agri-Food Canada to ensure that the aforementioned capacity to administer emergency use applications is retained until no longer necessary from a technical (efficacy) and economic (affordable) perspective.

8. Conclusion

The experience CPMA members have gained through participation in the trials made possible by AAFC cost-sharing and capable scientific support is of great value. CPMA extends the association’s sincere appreciation to AAFC and in particular to Dr. Paul Fields for his involvement and valued advice.

The findings of the SF trials conducted under this initiative are disappointing. The two major SF trials described in this report and appendices did not yield the level and duration of control expected based on dose rates and CTs achieved. In light of the costs, these trials did not deliver an acceptable level of “value for money”. As also noted above, the trials did not deliver the level and duration of control expected by the customers of CPMA member firms in today’s climate of intensifying food safety scrutiny.

However, CPMA firms are looking forward to and require full registration of SF by PMRA to permit further evaluation under conditions of use comparable to those permitted in the past for MB. CPMA is mindful of all of the efforts of Dow AgroSciences to achieve full registration and to demonstrate efficacy of SF under less than ideal (essentially an interim registration and label use) and these efforts are gratefully acknowledged. We again note the full registration of SF is not completed and will be too late for 2009 trials.

CPMA member firms represent a small market for pest control service providers. This may be one reason that the pest control industry is not “scaling up” adaptation and demonstration of MB alternatives other than SF at rates anticipated.

Adoption of MB alternatives is being deterred by the costs associated with some of these alternatives. Both heat treatment and SF have been clearly demonstrated in Canada to be significantly more costly than MB at current market prices for MB and the alternatives. Cost is of major concern to CPMA members in the current economic climate but a consideration that has not been demonstrably factored to date in MBTOC's evaluation of CPMA's Critical Use applications.

Our final comment is that with the absence of significant quantities of MB, CPMA member firms have no choice but to evaluate MB alternatives and adopt one or more to best technological feasibility advantage. It is CPMA's view that at least two additional years (2009 and 2010) will be required to complete the adjustment.

Appendix 1:

Efficacy Assessment Report on Methyl Bromide Alternatives in Canadian Pasta Manufacturing Facilities

20 March 2009

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Appendix to: Harrison G. 2009. Evaluation of Alternatives to Methyl Bromide for use in Structural Fumigation of Canadian Pasta Manufacturing Facilities 2007/2008: Report to Agriculture and Agri-Food Canada for project funded under Advancing Canadian Agriculture and Agri-Food Program.

Summary

Methyl bromide (MB) is a very effective broad spectrum fumigant. It is the major tool to control insects in food processing facilities, such as flour mills, pasta production plants and breakfast cereal plants. In 1992, methyl bromide was recognized as a significant ozone depletor and its consumption was frozen in 1995 and phased-out in 2005 in developed countries. After this time, countries must receive Critical Use Exemptions (CUE) to use methyl bromide. These have been granted for pasta plants in Canada. At the request of the Canadian Pasta Manufactures Association (CPMA), the Government of Canada has applied for and received CUE for methyl bromide for some pasta plants in Canada; 10.5 t in 2005, 10.5 t in 2006, 6.8 t in 2007, 6.1 t in 2008 and 4.7 t in 2009. An application for 4.7 t for 2010 is under review.

Given the pressing need to find alternatives to methyl bromide fumigation in pasta plants in Canada, the CPMA received funding from Agriculture and Agri-Food Canada to assist CPMA member companies to test alternatives to methyl bromide in 2007 and 2008, and to compare these alternative treatments to standard methyl bromide treatments. There were three trials with sulfuryl fluoride (SF, ProFume®, Dow AgroSciences), five trials with methyl bromide. The trials took place at three pasta plants across Canada, plants varied in size and age and the trials took place in both summer and fall.

The treatments were characterized by measuring temperatures and gas concentrations. The efficacy of treatments was estimated in two ways; bioassays and trapping. For the bioassays, just before the treatments, vials containing adults and eggs of the red flour beetle (*Tribolium castaneum* (Herbst)) were placed throughout the plant to determine efficacy. For trapping, pheromone traps were placed throughout the plant to estimate flour beetle populations within the plants before and after treatments.

Bioassays: Both MB and SF treatments were effective in killing 100% of adult red flour beetles put out as bioassays. All eggs were killed in the MB fumigation. In the SF treatments, egg mortality ranged from 69 to 81%. Some of the egg survival could be due to doing partial fumigation and leaky sections of the mill.

Trapping: Plant # 2 never caught any insects in the traps despite traps being used well before the MB and SF fumigations. Plant # 3 did not place the traps before the MB fumigation, so there is no estimation of populations before the treatment. Insects caught in the traps rose after the MB fumigations in Plants # 1 and 3. In Plant # 1, insects were trapped immediately after MB fumigation, but populations did not rise to pre-treatment levels within the 20 weeks of sampling. After the SF fumigation, populations rose to 100% of pre-treatment levels in 12 weeks in Plant #1 and #3.

Comparing the SF fumigations with the MB fumigations is difficult, because pest pressures change from year to year, weather conditions change from year to year, two of the three SF fumigations were partial fumigations, pheromone trapping did not start before MB fumigations in Plant # 3, and Plant # 2 had populations to low to measure the effect of fumigation.

Plants # 1 and 3 replaced a MB fumigation with the SF, and did not have to redo the fumigation with MB. However, in plant # 3, additional pest control measures, fogging with dichlorvos and sanitation, were needed after the SF fumigation, that were not needed after the MB fumigation.

Introduction

Methyl bromide (MB) (Fields and White 2002) is a very effective broad spectrum fumigant. It is used around the world to control a wide variety of pests (pathogens, nematodes, weeds and insects) in diverse substrates (soil, food, museum artefacts, buildings, equipment and aircraft). It is the major tool to control insects in food processing facilities, such as flour mills, pasta production plants and breakfast cereal plants.

In 1985, British scientists discovered a "hole" in the stratospheric ozone layer in the Antarctic. The ozone layer filters out harmful ultraviolet radiation, allowing life as we know it to survive and flourish on the planet. It was determined that chlorinated fluorocarbons were responsible for this reduction in the ozone layer. This prompted the creation in 1987 of the *Montreal Protocol on Substances that Deplete the Ozone Layer*, and it has been ratified by 191 countries. The goal of the Montreal Protocol is to eliminate substances that cause the depletion of the stratospheric ozone layer (MBTOC 2006).

In 1992, methyl bromide was recognized as a significant ozone depletory, and its consumption was frozen at 1991 levels starting in 1995. In 1997, Parties agreed to phase out methyl bromide starting in 2005 with interim reductions along the way. These dates are 10 years later for developing countries. Given that methyl bromide is such a widely used fumigant, in 1997 Parties also agreed to allow critical use exemptions (CUE) for very specific uses of methyl bromide. Users must demonstrate that there are no technically or economic alternatives to methyl bromide, and they are actively investigating alternatives to methyl bromide. CUE have been granted for some pasta plants in Canada. At the request of the Canadian Pasta Manufactures Association (CPMA), the Government of Canada has applied for and received CUE for methyl bromide for some pasta plants in Canada; 10.5 t in 2005, 10.5 t in 2006, 6.8 t in 2007, 6.1 t in 2008 and 4.7 t in 2009. An application for 4.7 t for 2010 is under review.

Given the pressing need to find alternatives to methyl bromide fumigation in pasta plants, the CPMA received funding from Agriculture and Agri-Food Canada to assist CPMA member companies in testing alternatives to methyl bromide in 2007 and 2008 and, to compare these alternative treatments to standard methyl bromide treatments. This project examines the efficacy of sulfuryl fluoride compared with methyl bromide fumigations. This project uses similar methods for evaluation as two previous projects to evaluate methyl bromide alternatives in Canadian flour mills (Harrison 2004, 2007).

Sulfuryl fluoride (SF or SO_2F_2) has been proposed as a replacement for methyl bromide in the fumigation of flour mills and other structures (Bell et al. 1996, Banks 2002, Welker et al. 2004, Williams 2005). Sulfuryl fluoride was originally registered for termite control in 1961, under the trade name Vikane®. It is registered for this use in USA, Germany, Sweden, China, Japan and the Caribbean. Since 1995, Dow AgroSciences has been expanding the use pattern of sulfuryl fluoride for use in food processing facilities, under the trade name ProFume® (Schneider, and Hartsell 1999, Welker et al. 2004). Currently ProFume is registered in USA, France, Switzerland, Germany, Italy, Belgium, United Kingdom, Ireland, Australia, Trinidad and Tobago, Mexico, Mauritius and Greece. Dow AgroSciences has applied for food tolerances in Canada, which would allow it to be used in facilities that have partially filled bins with flour and mill feeds, food additives and finished products, as is the case in the USA.

Methods

Treatments

The initial project only called for the assessment of two SF treatments and one heat treatment. Dure to concerns over damage to equipment by heat, the heat treatment was replaced with an SF treatment. However, some partial data sets were obtained on 5 MB treatments that were followed in addition to the three SF treatments.

Plant # 1 had a MB treatment on May 19, 2007, 5 May 5, 2008 and September 27, 2008 and a partial SF treatment on October 6, 2007. As SF can not come into contact with food or food ingredients, not all of the plant was treated. The regrind area, which takes pasta and grinds it into semolina, is separate from the production area in the middle of one of the warehouses. It was sealed and treated with SF.

Plant # 2 had a MB treatment on June 30, 2007 that treated the processing, warehouse, packing and semolina receiving areas. On October 6, 2007, they had a SF treatment of just the semolina receiving area. This area is adjacent to the processing area, doors and vents leading to the processing area and the outside were sealed before the fumigation.

Plant # 3 initially had planned an SF treatment of their entire facility in 2007. However, due to uncertainty in the support of the project, they did a MB treatment on June 30, 2007. They did an SF fumigation of their entire facility the following year, on June 28, 2008.

The efficacy of fumigants depends upon several factors: susceptibility of insects to the fumigant, concentration, duration of exposure and temperature. The concentration is a combination of how much fumigant is released into the building and how quickly the fumigant leaks out of the building. The Concentration x Time (CT) value is obtained by multiplying the concentration of gas (g/m^3) by time (h). For most fumigants, within limits, the CT is relatively constant. In other words, if you double the concentration, you can half the time and still get the same mortality. The other important factor in a successful fumigation is good sealing of the structure before the fumigation. The gas tightness of a structure is measured by Half Loss Time (HLT). This is the time it takes for half the fumigant to leak from the building. High winds or poor sealing can significantly decrease HLT.

The Fumiguide™, is a computer program created by Dow AgroSciences to guide fumigators in ProFume fumigations. I used the Fumiguide as a consistent way to calculate the CT and HLT for both fumigants, methyl bromide and sulfuryl fluoride.

Dome traps
Dome traps (Figure 1) that are specific for trapping flour beetles were placed throughout the facilities, and the insects removed and counted each week. These traps were purchased from Trece Inc (http://www.trece.com/). The traps were in the facilities 6 to 20 weeks before the SF fumigations. The traps were baited with a pheromone for the confused and red flour beetles (*Tribolium confusum* and *Tribolium castaneum*) (Figure 2) and a vegetable oil attractant. The vast majority of insects caught in the traps were flour beetles, and those data are reported here. The insect numbers are expressed as a percentage of the pre-treatment populations. The mean number of insects/trap/day in the pre-treatment periods was calculated and the means divided by pre-treatment mean and multiplied by 100 to give a standardized measure of the efficacy.

Plant # 1 started trapping (18 traps) in July 2007, several weeks after a MB fumigation, but well before the SF fumigation. They have made the trapping part of their pest management program and made available the data from 2008 and 2009. Plant #2 started trapping (12 traps) well before the MB and the SF fumigation, but no flour beetles were ever found in pheromone traps, despite flour beetles being present in the plant. Plant # 3 started trapping (14 traps) after the MB fumigation. As there is no pre-treatment trapping, no trap data for Plant #3 is reported. Plant #3 started trapping 6 weeks prior to SF fumigation and continued 20 weeks after fumigation.

Bioassays
The red flour beetle, *Tribolium castaneum* (Steinbach strain), was used as a test insect. They were reared on white wheat flour with 5% brewer's yeast at 30^{o}C, 60% relative humidity. Twenty unaged adults of unknown sex were placed in 16 g of culture medium in plastic vials, 4-8 days before the treatment, and held at 20-30^{o}C, 60% relative humidity. So at the time of the treatment there were 20 adults per vial and an unknown number of immatures, of which most would be in the egg stage. Eggs are the stage most resistant to SF. Pupae are the stage most resistant to MB. Eight vials were used as untreated controls. They were treated as the insects exposed to the treatment, but they were not held in the plant during the treatment. Twenty-five vials (Figure 3) were placed throughout the facility a few hours before the treatment and retrieved a few hours after the end of the treatment. About half of the vials were placed in the middle of the facility and half of them near windows or doors. Data loggers (Hobo Dataloggers, Onset Computers Inc.) were placed with each vial, and the temperature recorded every 15 minutes.

Results

Fumigant
Plants took less than a day to prepare for the fumigation, the gas was held for 22 to 26 hours, and the plant employees were allowed back into the building 5-17 h after the end of the fumigation (Table 1).

For the SF fumigation in Plant #1 on October 6, 2007, regrind and bin rooms were especially leaky with half loss times of 2 to 5 hours resulting in CT below the target of 658 gh/m^3 (Tables 2, 3). In Plant # 2, the CT for SF was below the target of 600 gh/m^3, due to a leaky structure resulting in a low HLT of 4 h. The regrind room of Plant #1 and the semolina room of Plant # 2 had interior walls common to other areas of the plant that were not being fumigated. Normally, these adjacent areas would also be under fumigation, so leakage is not normally a problem. Even with that taken into consideration, the remaining areas of Plant #1 had a much lower HLT with SF (8.8 h) compared with the previous fumigation with MB (13.3 h). However, Plant # 3 had a longer HLT with SF (16.5 h) than with MB (9.9 h). Higher winds, differences in temperature or differences in sealing may account for these differences.

Methyl bromide CT values were much higher (298 to 573 gh/m^3) than that seen in the fumigations with flour mills (108-443 gh/m^3 average 286 gh/m^3) (Harrison 2007). Half loss times in the pasta plants were much longer (9.9 to 17 h) than in flour mills (1.2 to 12 h, average 5.4 h). This could be due to the pasta plants being newer structures and do not require explosion panels compared to flour mills.

In Plant # 3, after the SF fumigation in June 2008, additional foggings with dichlorvos were needed. There was a total of nine foggings of different sections of the facility, starting in August 2008 and continuing throughout the winter. Also, an additional cleaner was hired to increase the level of sanitation in the facility to prevent an increase in the insect population. These measures had not been required in the past after MB fumigations.

Bioassays:
Both MB and SF treatments were effective in killing 100% of adult red flour beetles put out as bioassays. In the sulfuryl fluoride treatments, average egg mortality ranged from 69 to 81%. All eggs were killed in the MB fumigation (Tables 1, 4, 5, 6, 7). Note, that the estimation of egg mortality is approximate, as the number of eggs varies from vial to vial. In the control vials, the number of adults that emerged from vials varied from 192 to 309 adults (247 $\pm$ 16, 8, mean $\pm$ SEM, n) for the October 6, 2007, SF fumigation of Plant #1. Therefore, egg mortalities from individual vials only give a rough estimate of survival at a given location, but all the vials taken together should give a good estimate of overall survival.

The lower than target CT due to more leakage than expected was probably the cause of the egg survival in SF fumigations. There were 25 bioassays, located throughout the building. Whereas, the gas was sampled at 10 locations in Plant #1 and Plant #3 and at 2 locations in Plant #2. This is sufficient sampling to estimate if more gas is needed in a particular area of the plant. However, there can be significant differences in gas at different locations in the building. For example, vial # 7 was located beside a door and had 61% immature mortality (Table 4). The CT for this area is 1005 gh/m^3 , which should be sufficient to kill all eggs, but the CT at the vial is probably lower due to leakage of gas out the door.

Traps
Only trap data from the SF fumigations in Plants # 1 and 3 are presented. Flour beetles were found in Plant # 2, however, Plant # 2 never caught any insects in the traps, despite traps being used well before the MB and SF fumigations.

After MB fumigation in Plant # 1 there were adults present right after the fumigation (Table 8). Insects caught in the traps rose after the MB fumigation in Plant # 1. Insects were consistently caught in traps 1 to 5 weeks after MB fumigation (Tables 2, 8). However, insects never returned to the pre-treatment levels after the MB fumigation in Plant #1 within in the 19-20 weeks post fumigation (Table 8). There is less data for the Plant # 3 MB fumigation, because traps were placed 3 weeks after the MB fumigation, so there is no estimation of populations before the MB treatment. Insects were consistently caught in traps 12 weeks after MB fumigation in Plant # 3.

After the SF fumigation, insects caught in traps in Plants # 1 and 3 rose to 100% of pre-treatment levels 11 and 12 weeks respectively, after the SF fumigation. Insects were consistently caught in traps 3 to 5 weeks after SF fumigations (Tables 2, 8, Figure 5).

Discussion

There are several alternatives to MB fumigation to control stored-product insects, the main ones being SF, heat, IPM and phosphine combination treatment (Harrison 2004, Harrison 2007, MBTOC 2006). These alternatives have mainly been used in flour mills, with little work being done in pasta manufacturing facilities.

This study followed three SF fumigations in pasta plants. Two of the fumigations were partial fumigations, with sections of the facility sealed off from SF. This caused excessive gas loss through leaking into other sections of the facilities. In 2007 and 2008, the label for ProFume only allowed fumigation of empty structures. Dow AgroSciences has applied for food tolerances for sulfuryl fluoride in cereals. This is under review by Health Canada, Pest Management Regulatory Agency. Being able to fumigate the entire structure, as done with Plant #3, will simplify the fumigation, and allow for better retention of the gas and hence more effective fumigations.

Comparing the SF fumigations with the MB fumigations is difficult, because pest pressures change from year to year, weather conditions change from year to year, two of the three SF fumigations were partial fumigations, pheromone trapping did not start before MB fumigations in Plant # 3, Plant # 2 had populations to low to measure the effect of fumigation and there are only three tests of SF. Plants # 1 and 3 replaced a MB fumigation with the SF, and did not have to redo the fumigation with MB. Immature mortality tended to be less with SF than with MB, although additional replication would be needed to verify this. Some of the immature survival could be due to doing partial fumigations, leaky sections of the plant and not achieving the target CT values.

All pasta facilities have extensive capacity for heating, so unlike flour mills, there would be no capital investment needed for boilers. There are several issues that would need to be addressed before heat could be used in any particular facility; heat sensitive equipment, changing of sprinkler heads, retro fitting of steam lines for heaters. However, there is one facility in the USA that has solved these problems, and it has been using heat for insect control for several years as replacement for methyl bromide (Subramanyam 2006).

The phosphine combination treatment (phosphine at 100 ppm, carbon dioxide at 5% and temperature at 30^{o}C) has been used extensively in the USA and tested 3 times in Canada (Harrison 2007). Pasta plants have sensitive equipment that would need to be protected, but flour mills have many sensitive electrical components, and they were successfully fumigated with the phosphine combination method.
The European Community has drastically reduced its use of MB. Denmark phased MB out in 1998, Germany 2005 and the EU has no Critical Use Exemptions for flour mills and pasta plants beyond 2007 (MBTOC 2007). The alternatives used in European flour mills have been mainly, increased sanitation, increased contact insecticides, SF and heat treatments. There are a few publications on the pest problems in pasta plants in Italy (Trematerra 2004, Trematerra and Süss 2006). The Italian facilities have a wider range of pests, (*Tribolium* spp., *E. kuehniella* Mediterranean flour moth and *Ephestia cautella* tropical warehouse moth) than found in Canada. Since the loss of methyl bromide a few years ago, the Italian pasta plants have been using a variety of methods to control insect pests; increased sanitation, increased use of contact insecticides, aluminium phosphide, heat and SF. There is the additional problem of the infestation of pasta by *Sitophilus* spp. in finished pasta and with insect

fragments in semolina used in traditional pasta plants (Pasquale Trematerra, personal communication). However, detailed information on how the Europeans are dealing with the loss of MB in pasta plants is not available, and efforts should be made to determine what alternatives they are currently using to replace MB and the challenges they are facing.
It is difficult to estimate the populations of insects in pasta plants. Flour beetles are small, cryptic and the populations are not uniformly distributed throughout the plant. Insect populations change rapidly. At 30^{o}C, 70% relative humidity, red flour beetle populations increase 70-fold per month. For example, a small population of 10 red flour beetles if left undisturbed would increase to 700 in one month and to 50,000 in 2 months. Also sanitation practices can vary from plant to plant, or from month to month in a given plant, causing populations increase or to decrease independent of the fumigant used.

Conclusions

- Pest populations as measured by pheromone trap catches returned to pre-treatment levels approximately 3 months after SF fumigations in 2 plants.
- Although adult insects were trapped immediately after MB fumigations, trap catches after MB fumigations in one plant remained below pre-treatment populations for over 5 months.
- Bioassays demonstrated that both SF and MB killed all adults, and immature mortality tended to be less with SF than with MB. Additional replication would be needed to verify this.
- Two of the pasta plants successfully replaced their MB fumigation with SF.
- One plant required additional sanitation and contact insecticide treatments after the SF fumigation that was not required after the MB fumigation.
- Food tolerances for SF will simplify fumigations and should make them more effective.
- Other alternatives; such as heat, or phosphine combination treatments could be used in pasta plants.

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Table 1. Duration of treatments.

Treatment	Mill #	Start Date	Plant Preparation Time (h)	Duration of Treatment (h)	Duration of Post treatment (h)*	Total Plant Shut Down Time (h)
MB	1	19 May 07	14.0	24.0	16.5	55.5
MB	2	30 June 07	17.5	24.0	6.5	48.5
MB	3	30 June 07	-	22.75	6.0	-
SF	1	6 Oct. 07	8.25	26.25	4.5	47.5
SF	2	6 Oct. 07	-	24.25	-	-
SF	3	28 June 08	23.0	22.0	6.5	138.0

*Plant employees allowed back in building at end of post treatment phase.

Table 2. Summary of efficacy of MB or SF fumigations in Canadian pasta plants.

Gas	Plant #	Start Date	Temp. Inside (°C)	Temp. Outside (°C)	Total Gas Added (g/m^3)*	Gas CT (gh/m^3)	Gas Half Loss Time (h)	Bioassay Adult Mortality (%)	Bioassay Immature Mortality (%)	Trap catches Rebound Time (wks)	
										Regularly Found**	100% ***
MB	1	19 May 07	27.3	16.3	26	447	13.3	100	100	5	-
MB	1	5 May 08	-	-	26	494	12.3	-	-	1	never
MB	1	27 Sept. 08	-	-	26	488	12.3	-	-	3	+ 20
MB ****	2	30 June 07	29.0	20.0	-	573	17.1	100	100	-	-
MB ****	3	30 June 07	30.9	17.4	22	298	9.9	100	100	12	-
SF	1	6 Oct. 07	29.2	11.0	62	863	7.7	100	81	3	12
SF	2	6 Oct. 07	27.6	12.1	59	461	4.0	100	69	-	-
SF	3	28 June 08	30.5	21.8	58	712	16.5	100	94	5	12

* g/m^3 is very close to oz/1000 ft^3
** 3 consecutive weeks of insects trapped some where in plant, Plant #1 MB 19 May 2007 trapping only started 5 weeks post fumigation
*** Weeks for populations to return to 100 % pre-treatment levels
**** No pre-trapping before fumigation, therefore unable to calculate time to rebound to 100%

Table 3. Concentrations of SF in different areas of Plant # 1 and survival of bioassay insects.

Fumigant	Plant #	Start Date	Location	Gas CT (gh/m^3)	Gas Half Loss Time (h)	Bioassay Adult Mortality (%)	Bioassay Immature Mortality (%)
SF	1	6 Oct. 07	New Bin Room	492	1.9	100	53
SF	1	6 Oct. 07	Regrind	412	5.1	100	33
SF	1	6 Oct. 07	Rest of Plant	965	8.8	100	89

Table 4. The temperatures and survival of red flour beetle adults and immatures held at the various locations in Plant # 1, during the methyl bromide fumigation, CT = 447 gh/m^3; sulfuryl fluoride fumigation, CT = 863 gh/m^3.

Vial #	Location	MB Fumigation, May 2007			SF Fumigation, October 2007		
		Average Temp.* (°C)	Adult Mortality (%)	Immature Mortality (%)	Average Temp.* (°C)	Adult Mortality (%)	Immature Mortality (%)
1	Hog feed	29.5	100	100	33.8	100	99
2	Hog feed	27.2	100	100	34.2	100	100
3	2nd floor	29.7	100	100	31.8	100	98
4	2nd floor	32.0	100	100	33.8	100	100
5	2nd floor	31.2	100	100	33.6	100	99
6	#18 line	31.3	100	100	34.4	100	100
7	#18 corner, door	28.5	100	100	25.7	100	61
8	#18 centre	31.2	100	100	35.0	100	100
9	Bin floor	35.1	100	100	36.1	100	100
10	Bin top	32.9	100	100	33.6	100	100
11	#5 line	30.2	100	100	33.8	100	98
12	#5 floor	29.3	100	100	30.9	100	92
13	#5 floor	30.4	100	100	32.8	100	99
14	New bin room floor	21.7	100	100	25.0	100	46
15	New bin room top	25.7	100	100	26.2	100	59
16	Semolina top	19.1	100	100	23.5	100	55
17	Semolina floor	23.9	100	100	23.7	100	59
18	Rebolt sifter floor	24.3	100	100	26.0	100	98
19	Rebolt sifter	25.1	100	100	25.7	100	100
20	Process silo	22.4	100	100	24.5	-	-
21	Process silo	22.9	100	100	24.8	-	-
22	Process silo	23.5	100	100	29.7	100	97
23	Regrind	27.0	100	100	26.2	100	32
24	Regrind	24.8	100	100	26.4	100	48
25	Regrind	25.0	100	100	26.2	100	21
Mean		27.4	100	100	29.5	100	81

* Outside temperature for MB fumigation was 16.3 °C, for the SF fumigation it was 11.0 °C.

Table 5. The temperatures and survival of red flour beetle adults and immatures held at the various locations in Plant # 2, during the June 2007 methyl bromide fumigation, CT = 573 gh/m^3.

Vial #	Location	Average Temp.* (°C)	Adult Mortality (%)	Immature Mortality (%)
1	Regrind	29.0	100	100
2	Bin #4 top	28.9	100	100
3	Bin #3 top	30.2	100	100
4	Bin room floor	27.0	100	100
5	Bin, dust collector	30.4	100	100
6	Die room	29.2	100	100
7	Line 1 top	32.3	100	100
8	Line 2 floor	32.0	100	100
9	Cooler	31.0	100	100
10	1st mixer	31.7	100	100
11	Control panel	30.7	100	100
12	2nd floor production	33.7	100	100
13	Storage silo	30.4	100	100
14	Packing line	30.1	100	100
15	Palletizer	28.5	100	100
16	Packing area	29.1	100	100
17	Dryer top	32.8	100	100
18	Lab	27.6	100	100
19	Warehouse	26.8	100	100
20	Warehouse	26.7	100	100
21	Warehouse	25.1	100	100
22	Warehouse ceiling	27.5	100	100
23	Warehouse	22.9	100	100
Mean		29.3	100	100

* Outside temperature for MB fumigation was 20.0 °C.

Table 6. The temperatures and survival of red flour beetle adults and immatures held at the various locations in Plant # 2, during the October 2007 partial sulfuryl fluoride fumigation of semolina bin room, CT = 461 gh/m^3.

Vial #	Location	Average Temp.* (^oC)	Adult Mortality (%)	Immature Mortality (%)
1	Regrind	29.2	100	74
2	Bin #4 inside	28.4	100	93
3	Bin #3 top	28.4	100	87
4	Bin room floor	24.4	100	58
5	Bin, dust collector	28.6	100	77
6	Bin #4 top	28.1	100	56
7	Door to production	29.3	100	90
8	Door to outside	26.5	100	62
9	Top regrind silo	27.8	100	47
10	Sifter inside	28.2	100	51
Mean		27.9	100	69

*Outside temperature for the SF fumigation was 12.1 ^oC.

Table 7. The temperatures and survival of red flour beetle adults and immatures held at the various locations in Plant # 3, during the methyl bromide fumigation, CT = 298 gh/m^3; sulfuryl fluoride fumigation, CT = 712 gh/m^3.

Vial #	Location	MB Fumigation, June 2007			SF Fumigation, June 2008		
		Average Temp.* (^{o}C)	Adult Mortality (%)	Immature Mortality (%)	Average Temp.* (^{o}C)	Adult Mortality (%)**	Immature Mortality (%)**
1	Roof access	33.9	100	100	32.2	100	100
2	Line #1 electrical	32.7	100	100	32.4	100	60
3	Line #1 wall	32.6	100	100	31.5	100	100
4	Line #1 floor	29.1	100	100	30.9	100	100
5	Line #1 wall	27.1	100	100	28.1	100	100
6	Line #5 end	31.2	100	100	31.2	100	100
7	Line #5 middle	32.1	100	100	31.5	100	100
8	Line #5 start	33.5	100	100	34.3	100	100
9	Bin room vent	30.6	100	100	29.5	100	100
10	Die room	26.0	100	100		100	100
11	Line #9 start	34.8	100	100	33.0	100	100
12	Line #9 middle	35.6	100	100	33.3	100	100
13	Line #9 end	34.1	100	100	32.5	100	100
14	Lockers	32.1	100	100	31.8	100	100
15	Exit NW	26.7	100	100	28.3	100	100
16	Exit WN	28.7	100	100	27.8	100	100
17	Warehouse	33.9	100	100	32.8	100	100
18	Exit WS	29.1	100	100	27.8	100	100
19	Stair well	29.3	100	100	28.5	100	80
20	Bin basement west		100	100	25.1	100	80
21	Bin basement east	27.0	100	100	25.3	100	60
22	Sifter west	29.8	100	100	31.5	100	80
23	Sifter exit east	32.9	100	100	29.2	100	100
24	Dust collector west	33.6	100	100	34.6	100	80
25	Dust collector east	33.3	100	100	34.4	100	100
Mean		31.2	100	100	30.7	100	94

*Outside temperature for MB fumigation was 17.4^{o}C, for the SF fumigation it was 21.8 ^{o}C.
** Bioassays in this test were not a good indicator of efficacy, as untreated insects had 17 % mortality for adults and produced only 5 offspring/vial.

Table 8. Red and confused flour beetle (average percent pre-treatment) adults found in pheromone baited traps, from pasta plants that were treated with sulfuryl flouride.

	Trap Catch (% pre-treatment)			
Method	SF	MB*	MB*	SF
Plant #	1	1	1	3
Date (m/y)	Oct. 2007	May 2008	Sept. 2008	June 2008
Post-treatment (wks)				
-6	67	74	86	68
-5	84	116	142	103
-4	135	86	87	90
-3	103	129	89	93
-2	126	151	98	111
-1	85	43	99	136
1	0	11	35	1
2	0	13	0	0
3	3	5	13	0
4	8	4	4	0
5	21	7	6	4
6	29	10	6	2
7	24	7	12	2
8	21	21	2	1
9	23	13	7	3
10	20	16	6	13
11	0	7	7	37
12	176	19	11	132
13	58	20	11	62
14	91	46	42	47
15	188	76	14	86
16	106	47	23	135
17	176	48	53	126
18	32	53	32	193
19	67	53	32	103
20	68		61	103
21	59			
22	150			
23	248			
24	246			
25	226			
26	356			
27	264			
28	396			
29	463			
30	132			

* These values are different from Figure 5 because these pre-treatment values are recalculated for each fumigation, whereas values in Figure 5 are always in precent of the SF pre-treatment.

Figure 1. Trap baited with pheromones for the confused and red flour beetles (*Tribolium confusum* and *Tribolium castaneum*), common pests of pasta plants, flour mills.

Figure 2. The red flour beetle (*Tribolium castaneum*), a common pest of pasta plants, flour mills.

Figure 3. Vial with red flour beetle (*Tribolium castanenum*) adults and eggs used for bioassays and a temperature data logger.

Figure 4. (above) Cylinders of sulfuryl fluoride gas (ProFume) used in treatments, (below) gas injection lines entering pasta plant so that gas can be distributed to different areas of the facility.

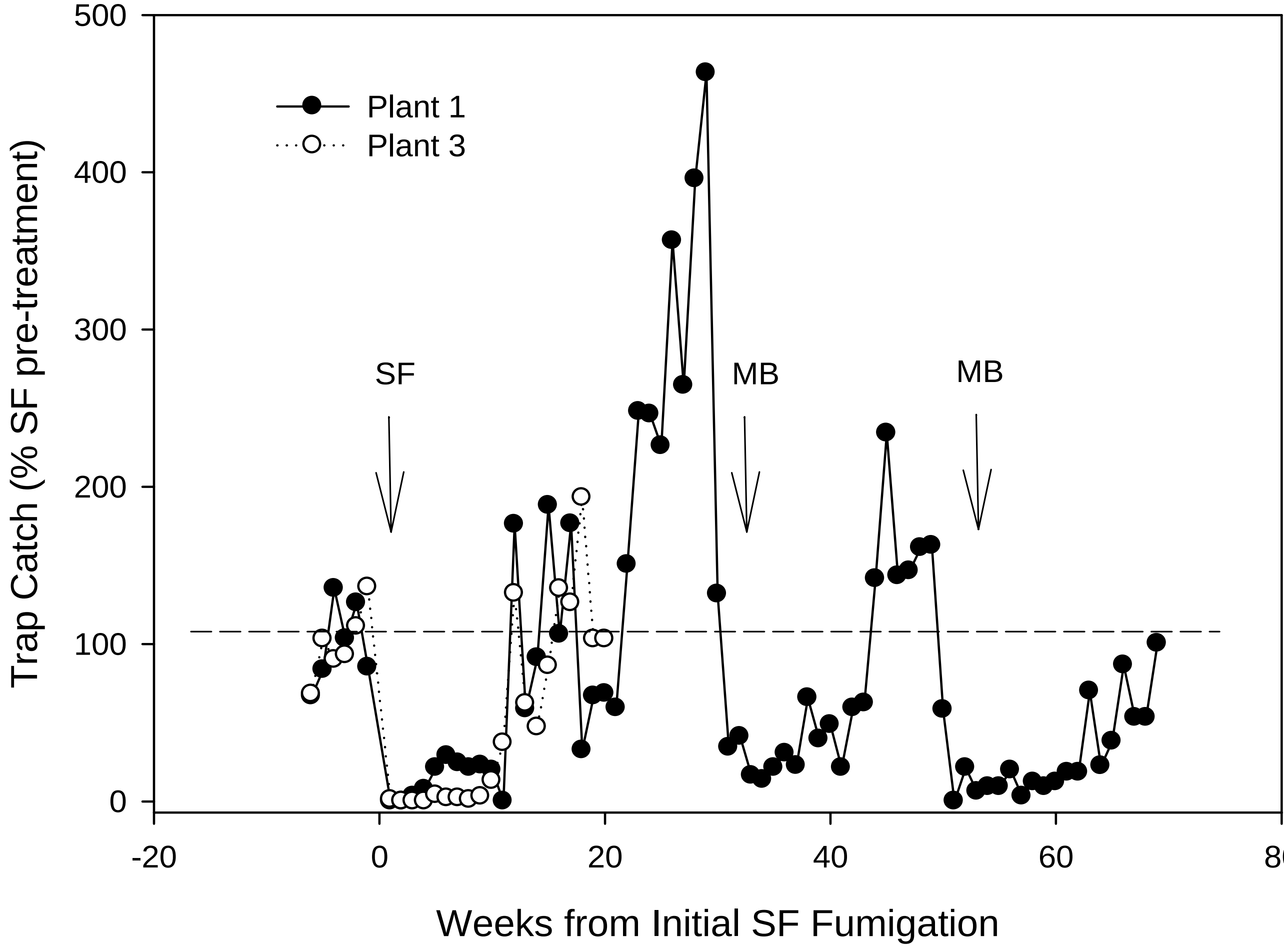

Figure 5. The pheromone trap catch of flour beetles in Plants # 1 and 3 before and after a fumigation with sulfuryl fluoride. Plant # 1 continued trapping 60 weeks after SF fumigation (Oct. 2007) with a spring and fall MB fumigation in 2008. All numbers as % of SF pre-treatment.

Appendix 2

Evaluation of Alternatives to Methyl Bromide in Canadian Pasta Manufacturing Facilities in 2007/2008: An Interim Report

Prepared for Agriculture and Agri-Food Canada and Environment Canada

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INTRODUCTION

This document is an interim report on a series of site-specific trials (test treatments) being conducted in 2007/2008 to evaluate the feasibility and efficacy of pest control methods and products that are potential alternatives to fumigation of pasta manufacturing facilities with methyl bromide. The complete report will be available in late 2008, including the findings of additional trials planned for second and third quarter of the year. This report is offered to provide some additional insight to Environment Canada and the Methyl Bromide Technical Options Committee (MBTOC) of the Montreal Protocol to assist in evaluation of Canada's current Critical Use Nomination for structural fumigation of Canadian pasta manufacturing facilities.

Project Rationale and Overview

Readers of this report are very likely to be familiar with the provisions of the Montreal Protocol and Canada's related regulated phase-out of industrial use of the chemical fumigant, methyl bromide (MB) as a consequence of its ozone-depleting properties. MB has for many years been used as a highly effective tool in controlling stored insect pest populations in grain processing and further processing facilities such as flour mills, breakfast cereal plants and pasta manufacturing plants in Canada and many other countries.

In keeping with Canada's commitments as a party to the Montreal Protocol, Environment Canada, the relevant federal regulatory department, has by regulation prohibited use of MB for structural fumigation (of all categories of grain processing facilities) except under provisions of Critical Use or Emergency Use exemptions. Canadian pasta manufacturers have access to reduced and declining quantities of MB under approved and pending Critical Use Exemptions (CUE). However, the quantities of MB available in 2008 will be substantially below historical use requirements for effective pest control.

Accordingly, the Canadian Pasta Manufacturers' Association (CPMA) sought and secured funding assistance under Agriculture and Agri-Food Canada's ACAAF program. This is a program that is generally available to agriculture and food sectoral organizations to address emerging challenges and opportunities. ACAAF is currently funded through March of 2009. CPMA's contribution agreement with ACAAF terminates in December of 2008. Under the provisions of the agreement, AAFC has agreed to share the cost with the participating CPMA members of conducting research trials to evaluate alternatives to MB. Planned and executed in 2007 were two trial fumigations using sulphuryl fluoride (SF) in the product form, ProFume.

This research is being conducted in collaboration with Dr. Paul Fields of AAFC's Cereal Research Centre. Dr. Fields is an entomologist who has been actively working with Canada's grain milling and pasta industries in recent years to assist in the evaluation and adoption of alternatives to MB. Dr. Fields has developed successful protocols for monitoring of insect pest populations before and after execution of trials. In addition to acting as an advisor to the participating milling and pasta firms, Dr. Fields has actively participating in the trials by

providing and placing vials of laboratory-reared live insects (flour beetles) to provide a means of evaluating efficacy (mortality achieved) of the trials.
Mortality rates of adult insects are readily assessed during and/or immediately after trials. The vials are subsequently kept under favourable laboratory conditions for sufficient time to determine mortality of larvae and eggs in all vials.

For this particular project, Dr. Fields is providing and placing assay vials, observing trials on site, assembling the relevant data and preparing an efficacy report similar to that prepared for previous trials of alternatives in Canadian grain milling facilities. His preliminary findings for the two SF trials completed to date are appended.

Additional details of Dr. Fields work in this area can be found in his various publications posted on the Cereal Research Centre web site (accessible via www.agr.gc.ca).

Recap of Stored Product Pest Control Challenges in Pasta Plants

The stored product pests of significance to pasta plants are flour beetles, grain beetles and Indianmeal moths. These species are widely present (indigenous) in all regions of Canada where industrial scale wheat milling and pasta manufacturing facilities are situated. Although these regions all have temperate climates (Zones 3 to 7) that experience moderate to severely cold temperatures in winter months (mid-November to mid-April), milling and pasta facilities offer ideal living environments for such pests year round.

In the case of pasta manufacturing facilities, the ambient temperature and humidity levels are usually optimal for insect breeding and growth. Although typically having much less airborne particulate (flour dust) than flour mills, pasta facilities can accumulate sufficient residues in building structure and processing equipment to provide an ample food supply for insect pests if left undisturbed for any significant period of time.

The ongoing cleaning and maintenance activities within pasta facilities generally succeeds in keeping insect pest populations restricted to the building structure (wall, floor and ceiling cavities, cracks and crevices) and structure/equipment interfaces that are not physically accessible to manually clean. Infestation of processing equipment is rare, as mixers, extruders and dryers are frequently cleaned and do not normally provide suitable harbourage for insects. Moreover, dryer (drying tunnels and conveyors) temperatures are generally too high to favour insect pests.

Areas of pasta facilities that can be prone to re-infestation (even following what are considered to be successful annual or semi-annual fumigations) are the wheat semolina receiving and storage areas, transfer equipment that moves semolina from bins to production lines and the regrind equipment and storage areas. “Regrind” refers to the area in which broken or physically out of specification pasta of food quality is briefly stored and then ground into semolina sized particles for reprocessing into finished pasta. This environment is not unlike that of grain mills in nature and can be conducive to infestation, particularly if insect eggs are reintroduced to the plant via shipments of wheat semolina from suppliers.

Although suppliers of semolina (wheat millers) themselves have ongoing integrated pest management programs and periodically conduct whole facility fumigations or heat treatments, semolina can be manufactured without successfully destroying all egg stages of insect pests. The reason for this is that semolina can only be sifted or otherwise separated out of milled wheat product streams and any insect eggs that may be present can pass through the final sifting process as the eggs are considerably smaller in size than semolina granules. Mills that produce semolina for pasta manufacturing seek to avoid this through high levels of sanitation, complemented historically by one or two methyl bromide fumigations annually. These have usually been scheduled to coincide with pasta facility shut-downs for fumigation and vice-versa. As is the case for pasta plants, such mills are actively evaluating alternatives to MB fumigation, including SF, as has been documented in previous ACAAF project reports completed by the Canadian National Millers Association.

It should be noted that even the most modern pasta production facilities contain areas that can potentially provide harbourage (breeding and living space) for stored product insect pests. Flour beetles can breed, mature and multiply in spaces and grain residue volumes as small as a few cubic centimetres. These conditions exist in the most state-of-the-art grain processing structures and equipment. The complete absence of stored product pests from a pasta facility over a period of years is most unlikely. Accordingly, the development and adoption of fumigation and/or heat treatment procedures that are feasible and efficacious alternatives to MB is an operating requirement, even if to have in place as a contingency.

Trials Conducted in 2007

There were two trial SF fumigations conducted in 2007. The company findings and observations are summarized as case studies below.

CASE STUDY 1: TRIAL FUMIGATION USING SULFURYL FLUORIDE

Facility Description

This pasta manufacturing plant is a large facility in terms of structural volume and configuration. The facility houses bulk raw material (durum wheat semolina) receiving and storage, packaging materials receiving and storage, pasta production lines, finished product warehousing, a mechanical maintenance shop, QA lab and offices.

Typical of many cereal grain processing (milling) and further processing (pasta, bakery, breakfast cereal) plants in Canada, this facility was constructed and renovated to its current productive state over many years. This has included very significant investment in process control equipment, packaging and ventilation/aspiration (dust control).

As a consequence, there is a range of construction methods and materials to be found in the building, including brick and block masonry walls that typically can provide harbourage (living space) for stored product insect pests. The cavities that are usually present in such masonry construction are compounded by the necessary routing of mechanical (steam supply and return, air) and electrical (conduits) equipment through the walls that make up the physical plant along with production and storage equipment.

In addition, the many units of pasta, production and packaging equipment constituting production lines come into contact in many locations with supporting infrastructure and floor areas. These areas also provide harbourage for stored product pests that cannot be reached for manual cleaning.

It is these structural characteristics, coupled with the life cycles and habits of stored product pests that render chemical fumigation of pasta facilities the preferred method of pest control.

The facility is equipped with steam boilers for comfort heat and for current and previous processing requirements.

There is one aspect of this facility to be noted for its implications in staging and scheduling pest control treatments. The main production area is physically separated from a portion of the plant designated the "regrind" area. "Regrind" refers to the re-milling of food-grade but physically damaged (broken or otherwise out of specification) pasta into semolina-sized particles for reprocessing. This presents not only the requirement but the opportunity of treating the regrind area separately at different times using different pest control methods.

This facility is also typical of most food processing facilities in that it normally operates 24 hours per day, 7 days per week in order to meet customer volume and delivery schedule requirements and to optimize productivity. As a consequence, the shut-down time associated with pest control treatments is sought to be as brief as possible while achieving the desired interruption in the insect pest life cycle.

Recent Pest Control Program

As a food production facility, the operation of this pasta plant incorporates an ongoing program of hygiene and sanitation (cleaning and preventive measures) that are a combination of manual cleaning of the facility and equipment plus operating procedures that contribute to plant hygiene.

This facility has been largely reliant upon chemical fumigation using methyl bromide for whole facility treatments (MB) for much of the recent past. The entire production area has been treated with methyl bromide twice per year in most years. Historically, fumigations also included the warehouse areas of the plant. However, this was discontinued in recent years as availability of methyl bromide has declined (and cost increased) due to regulated phase-out.

Between fumigations, company staff and pest control service personnel conduct an ongoing program of insect population monitoring, pheromone trapping and application of residual insecticides and other spot (limited area) treatments as the situation warrants.

As referenced above, the primary function of a plant fumigation is to dramatically reduce insect pest populations in the facility by killing all life stages (adult, larvae, eggs), thereby interrupting a life cycle that is as short as 21 to 28 days from egg to adult for some species (red and confused flour beetle). Following fumigations, any larvae or egg stages that survive the fumigation, can mature into breeding adults, over time resulting in a rebound of insect pest populations. This normally occurs first in the plant structural components where small populations can re-establish in protected spaces (cannot be reached to be manually cleaned) and ultimately migrate (crawl or fly) to other areas of the plant.

In this particular facility, years of experience have demonstrated that an integrated pest management program must include a "whole-facility" treatment of at least the production areas using chemical fumigation.

The preparation for a methyl bromide fumigation has typically been:

- The fumigation is usually scheduled to coincide with a weekend shut-down of semolina suppliers so that down-time coincides and pasta production down time is minimized.
- An intensive cleaning of the entire facility takes place in the 7 days leading up to the scheduled MB fumigation. This requires the addition of cleaning staff above the usual contingent.
- The advance cleaning allows for cleaning of the structure and physical plant except for the interior of production equipment.
- In the final 2 shifts before fumigation, production equipment except for packing lines is shut down. During the final shift, all production equipment is opened and disassembled to the extent design permits and the interior of the equipment is cleaned.
- Other measures are taken to power down the equipment lines and lock out equipment for manual cleaning.
- Areas of the plant that are not intended to be fumigation are sealed off from the areas to be fumigated by applying polyethylene and tape. In the case of MB, the purpose is to contain the gas within the intended areas to achieve required concentration and minimize gas use. The same is true for sulfuryl fluoride (SF) but due to limited use approval (approved MRLs), there is a requirement to prevent SF from coming into contact with semolina and/or finished pasta in storage or packing bins. As a consequence, there is a requirement to empty packing bins and lines before injection of SF to the facility. This is not a regulatory requirement for MB as is currently the case for SF.
- The final step of sealing is for exterior wall doors and other openings to improve gastightness (reduce rate of gas loss).

2007 Trial SF Fumigation

The trial fumigation with SF was conducted in this facility in October, 2007 over a weekend to coincide with a scheduled shut-down of the major semolina supplier to this pasta plant. The plant preparation was essentially as per the steps outlined above for a typical MB fumigation.

However, there were some differences in plant preparation. These were:

- The regrind material bulk totes that contained pasta destined for re-reprocessing needed to be isolated from the area to be treated with SF.
- The regrind equipment and receiving bin needed to be completely empty.
- The pest control service provider needed access to the facility to set up SF delivery and monitoring equipment. This required a period of approximately 6 to 7 hours.

In addition, a research scientist (Dr. Paul Fields of AAFC's Cereal Research Centre) required access to the plant to place vials of insects at various positions in the production and regrind areas as a means of measuring the rate of insect mortality achieved via the fumigation.

The volume of gas required and application rate were calculated in advance but adjusted to respond to ambient weather conditions. The SF was introduced to the mill from SF cylinders and manifolds positioned on the building exterior, from which point the applicator can monitor temperatures and concentrations within the plant.

The SF gas was injected into the plant to achieve the desired concentrations and topped up as necessary to maintain the target concentrations for the desired exposure time (20 to 24 hours). In this case the elapsed exposure time was in excess of 22 hours, beginning late afternoon on the first day and ceasing mid-afternoon on day 2. Venting of the facility required an additional approximately 8 hours. Dismantling of the equipment and test vials was completed late evening of day 2. Mill maintenance and production staff began preparation for start-up in the early morning hours of the third day, allowing re-starting of production by 8:00 a.m.

In total, the actual production (of pasta) down time associated with the trial SF fumigation was 60 hours, in keeping with past requirements for MB fumigations.

Lessons Learned

Logistics

- Plant preparation for fumigation of the production areas with SF was very similar in terms of time, labour and total costs to typical MB fumigations. Apart from requiring that all semolina, finished pasta and regrind pasta be removed, the preparation required was equivalent.
- Set-up of gas injection equipment and monitoring lines, plus staging of gas cylinders, manifold and monitoring equipment was accomplished within a reasonable time frame of less than 6 hours.
- Staging of the equipment and injection of the gas from a point exterior to the building was seen as an advantage from a worker safety perspective.
- The gastightness that had been observed in past MB fumigations was sufficient to conduct the SF fumigation largely as planned.

Efficacy

- Assay vials retrieved from the plant indicated that a number of vials had survival of eggs.

- Early observations (6 to 8 weeks) indicated that population rebound was being experienced sooner than would have been the case for a typical MB fumigation. There is some concern that this is as a result of the regrind totes not being able to be fumigated but there is no hard evidence to identify this as a source of re-infestation.
- Results of pheromone trap data (20 weeks) were not available at time of drafting this document.
- There may be a need to increase SF concentrations in future fumigations to achieve a higher level of egg stage mortality. Addition of heat (using comfort heating equipment and/or dryers) may also be considered to improve efficacy.

Please refer to ***Appendix 1: Interim Efficacy Assessment Report on Methyl Bromide Alternatives in Canadian Pasta Production Facilities*** for more detail.

Affordability

As noted earlier, this is a large facility. The cost of the SF fumigation exceeded $200,000, roughly 75% greater than the estimated cost in 2007 for a comparable MB fumigation of the same production areas of the building. The true assessment of affordability (cost-effectiveness) would suggest the need for an additional SF trial, adjusted to reflect lessons learned in the initial trial. For a facility of this size, there is truly a site-specific learning curve and it would have been unreasonable to expect the service provider and plant staff to execute a near-perfect fumigation on the first attempt.

Consideration of Other Alternatives to MB

- The October, 2007 SF trial was encouraging, all things considered. If experience can identify the appropriate gas concentration to achieve the required degree of mortality of all life cycle stages, SF would be considered to be a technically feasible alternative to MB.
- Feasibility would be further enhanced by the establishment of MRLs to permit contact with pasta and semolina under circumstances where the commodities cannot be removed from the plant or isolated during a fumigation.
- This SF trial illustrated that the regrind area of the plant might be suited to heat treatments that could be scheduled in tandem with or separately from future SF fumigations.
- Chemical fumigants containing phosphine are not being considered for this facility at this time due to equipment failure concerns. The plant's production schedule is sufficiently tight so as to provide for almost zero tolerance of even minor equipment failure following pest control treatments. This is a market acceptance obstacle that phosphine technology providers will have to overcome.
- The company is hopeful of conducting a second SF trial in 2008 in direct comparison with a MB trial in 2008.

CASE STUDY 2: TRIAL FUMIGATION USING SULFURYL FLUORIDE

Facility Description

This pasta manufacturing plant (referred to as Plant # 2 in the appended efficacy report) is quite typical of pasta and other cereal grain further processing facilities. The major components or areas of the building are:

- Administrative and management offices
- Bulk ingredient (semolina) receiving, storage and primary handling/transfer, including the regrind equipment for recycling out-of-spec food quality finished pasta
- Packaged ingredient and packaging material storage area
- Principal manufacturing area
- Electrical and control room
- QA and product development laboratory
- Finished product warehouse and shipping

All of the major manufacturing area, including packaging lines, is contained within one large building space that is a very large volume, single storey structure. Partitioned off from this large production area but immediately adjacent are the electrical and control room and the semolina receiving/storage/transfer/regrind room, both adjacent.

The warehouse areas (inputs and finished products) are partitioned from the production area, as of course are the offices and lab. All are contained within one integrated structure that is relatively new and of modern construction. The construction is a mix of steel superstructure for building frame and support of large equipment, reinforced concrete floors, masonry block partitioning walls, insulated exterior metal cladding and roof.

The building is situated in an area of multi-use commercial buildings, well removed from residential areas but within 30 metres of a major roadway serving a major portion of the industrial area. There is little to no pedestrian traffic in the area. As a consequence, gradual dissipation and controlled venting of chemical fumigants is not a major safety concern.

As in other pasta manufacturing facilities, production and packaging equipment constituting production lines come into contact in many locations with supporting infrastructure and floor areas. These areas are difficult to reach by manual cleaning methods. Otherwise, the facility is spacious and generally accessible for continuous plant hygiene activity and has excellent ventilation and dust control capacity.

The facility normally operates at a high level of capacity utilization, 24 hours, 7 days per week. Strategic scheduling of shut-downs for major pest control treatments is therefore a requirement for this operation, like most others that are operating in today’s food processing commercial environment.

Recent Pest Control Program

The operation of this pasta plant incorporates an ongoing program of hygiene and sanitation (cleaning and preventive measures) that are a combination of manual cleaning of the facility and equipment plus operating procedures that contribute to plant hygiene. Dust control is enhanced by the operation of mixing equipment under negative pressure (aspiration).

The ongoing program of plant hygiene has kept insect populations to minimal or non-detectable levels (pheromone trapping does not indicate presence of even minor infestations during most of the year, with some historical exceptions) in most areas of the facility. However, as a largely preventive measure in most years and to address insect populations in the semolina and regrind area of the plant, the facility has been subjected to whole-facility treatments using methyl bromide as part of the integrated pest management program.

The facility staff consider the most probable source of stored product pests to be living eggs in bulk semolina shipments. Durum semolina that is produced by wheat millers is a coarse granular product by intent that cannot be subjected to high velocity impact (entoleter treatment) as a means of killing any insect larvae and eggs that may be present within the semolina (please refer to report introduction). Semolina can only be sifted or otherwise separated out of milled wheat product streams and insect eggs that may be present in the product streams can pass through the final sifting process made before shipping to pasta plants.

The preparation for a methyl bromide fumigation has typically been:

- The fumigation is usually scheduled to coincide with a weekend shut-down of semolina suppliers so that down-time coincides and pasta production down time is minimized.
- An intensive cleaning of the entire facility takes place over several days leading up to the scheduled MB fumigation.
- All production equipment is opened and disassembled to the extent design permits and the interior of the equipment is cleaned. Some of the semolina receiving and transfer equipment has been modified from its original design and construction to add access points for cleanout and gas access during fumigation.
- Exterior wall doors and other openings are sealed to improve gastightness (reduce rate of gas loss).

It should be noted that in past MB fumigations, since the production, warehouse, laboratory, semolina and electrical rooms have all been fumigated simultaneously, there has not been a requirement to partition off any area of the plant with the exception of the warehouse in more recent years as available volumes of MB have declined due to regulated phase-out.

This was not the case for the SF trial in 2007, as explained in the section to follow.

2007 Trial SF Fumigation

This partial facility trial fumigation with SF was conducted in October, 2007 over a 3-day holiday weekend. The plant preparation was essentially as per the steps outlined above for a typical MB fumigation. There were no extraordinary measures taken to prepare the limited area to be treated, the semolina receiving, transfer and regrind room except for the requirement to empty all bins and equipment of semolina and pasta waiting to be reground. This was required to avoid contact between food materials and SF since there is no established maximum residue limit for SF in Canada.

There was a limited amount of sealing (polyethylene film and tape) to be done as there are only personnel doors to the exterior, limited window space and one door connecting to the main manufacturing area of the plant.

In addition, a research scientist (Dr. Paul Fields of AAFC's Cereal Research Centre) required access to the area to place vials of insects at various positions as a means of measuring the rate of insect mortality achieved via the fumigation. This has been the standard approach to measuring short term efficacy in all flour mill and pasta facility trials of MB alternatives in Dr. Fields' research.

The volume of gas required and application rate were calculated in advance but proved to be insufficient to reach and sustain the target concentration limit. The pest control service contractor stopped the injection of additional SF when it became apparent that the area to be fumigated was insufficiently gas-tight to retain the SF. It was determined that the SF was leaking from the area into the roof space and/or the adjacent electrical control room and/or the immediately adjacent portion of the production space. As a consequence, the target gas concentration and exposure time were not achieved.

Lessons Learned

Logistics

- Plant preparation for fumigation of the production areas with SF was very similar in terms of time, labour and total costs to typical MB fumigations. Apart from requiring that all semolina, finished pasta and regrind pasta be removed, the preparation required was equivalent.
- Set-up of gas injection equipment and monitoring lines, plus staging of gas cylinders, manifold and monitoring equipment was accomplished within a reasonable time frame.
- The very small area (and volume) of the portion of the plant fumigated required very small quantities of SF gas.
- The acceptable gas-tightness that had been observed in past MB fumigations of the whole plant including the production area was not found to exist for the small area to be fumigated (semolina room).

- In the absence of being able to somehow permanently or temporarily seal off the semolina room from the other areas of the plant, it would appear that chemical fumigations of the semolina room alone will not be feasible.
- This suggests that the only means of control measures using chemical fumigants will be whole facility fumigations, regardless of cost implications or actual need in other areas of the plant.
- The company is now actively considering heat treatment as an alternative to chemical fumigation for an additional trial treatment of the semolina room. There are concerns about sensitivity of equipment that are being fully examined before a decision can be taken on a heat treatment trial.

Efficacy

- Assay vials retrieved from the plant indicated that a number of vials had survival of eggs.
- Efficacy (mortality) of indigenous insects (those not imported in the assay vials) was really not possible to assess since pre-treatment monitoring and pheromone trap counts over the prior several months did not indicate an infestation of any of bins, transfer or regrind equipment prior to the treatment.
- Early observations (6 to 8 weeks) post-treatment have not indicated presence of insect pests in the treated area of the plant or other areas.
- Results of pheromone trap data (20 weeks) were not available at time of drafting this document.

Please refer to ***Appendix 1: Interim Efficacy Assessment Report on Methyl Bromide Alternatives in Canadian Pasta Production Facilities*** for more detail.

Affordability

Had the area fumigated proven to be sufficiently gas-tight, fumigation with SF as an alternative to MB would have been considered an affordable alternative.

However, since SF use would dictate a whole facility fumigation, there would be a significant cost increase (gas prices predominantly) over historical whole facility fumigation costs.

Consideration of Other Alternatives to MB

Since this particular pasta facility and its operating staff have been able to achieve a high level of pest control through an integrated pest management approach with emphasis on equipment cleaning and plant hygiene, what is required is a MB alternative that is suitable for use in areas of the plant that have experienced a moderate but higher frequency of stored product pest infestations. For reasons outlined above (gas half loss time experienced), heat treatment may be the next method to be evaluated as an option before plant modifications to achieve higher gas-tightness are considered.