ProFume® Gas Fumigant: Success of a New Post-Harvest Fumigant

Bob Williams, Ph.D.
Ellen Thoms, Ph.D.
John Busacca, Ph.D.
Dow AgroSciences USA

Kansas State University
Manhattan, KS
Heat Treatment Workshop May 13-15, 2009

©™Trademark of Dow AgroSciences LLC
ProFume and Vikane are federally Restricted Use Pesticides. Always read and follow label directions.
History of ProFume® gas fumigant

- Early 1950’s - Research by The Dow Chemical Company for an alternative to methyl bromide (MB) for structural fumigation

- 1961 – Vikane® gas fumigant, sulfuryl fluoride (SF) as the active ingredient, introduced to protect homes and structures from drywood termites and other pests

- Today - More than one million structures, including museums, cathedrals, historical landmarks, rare book libraries, and scientific and medical research laboratories, have been fumigated with Vikane to eradicate pests

Fumigation of Chemistry Research Building (1.4 million ft³), University of Florida, Gainesville, FL
History of ProFume® gas fumigant

- SF does not interact with or contribute to local ozone formation or stratospheric ozone depletion
- 1995 – At request of progressive food industries, Dow AgroSciences investigated SF as an MB alternative for post-harvest insect control
  - Dow AgroSciences formed partnerships with leading stored product researchers, fumigators and food industries around the world to develop ProFume

2007 - Dow AgroSciences named a winner of the United Nations Montreal Protocol Innovators Award and the US-EPA’s “Best of the Best” Ozone Protection Award
Key Benefits of ProFume®

- Broad-spectrum, effective and reliable control of all pest life stages
- Non-corrosive to equipment or electronics
- Non-flammable
- Low reactivity (no odor potential or off flavors)
- Excellent penetration & rapid aeration
- Flexibility to optimize current schedules and downtime
- Does not deplete ozone - sustainable chemistry
ProFume® Global Registration Status

- 2003 - First global registration in Switzerland for use in flour mills
- Since then, ProFume has been registered in an additional 14 countries
  - 2004 – USA, Italy, UK & Germany
  - 2005 – Belgium
  - 2006 – Canada & France
  - 2007 – Ireland, Spain, Trinidad and Tobago, Mexico, Australia
  - 2009 - Greece
ProFume® Global Registration Status

- 2006 – CODEX Alimentarius Commission approved MRLs for sulfuryl fluoride for international trade
- 2008 – European Union set MRLs (Maximum Residue Limits) for sulfuryl fluoride and fluoride in various commodities (Annex III of 396/2005/EC)
General Use Pattern

- Varies based on country registration
- Residential and/or non-residential structures
- Stationary transportation vehicles (railcars, shipping containers, trucks, etc., excluding aircraft)
- Temporary and permanent fumigation chambers
- Storage structures
- Food handling establishments (e.g., pet food facilities, bakeries, food production facilities, mills, warehouses, etc.)
419 known fumigation jobs at 250 locations in 31 US states, Puerto Rico, and 3 Canadian Provinces and have been fumigated using ProFume
- 52% verified with Fumiguide™ data
- 38% of the structures have been fumigated 2-8 times with ProFume over successive years, indicating customer satisfaction and adoption
- Average 12 ProFume fumigations per month during 7-month fumigation season from March through September

Farmer's Rice Cooperative, Sacramento, California, USA

Rice mills representing 50% of the USA rice processing have converted to ProFume
# ProFume Parameters in N.A. by Fumigation Category, 2004-2008

<table>
<thead>
<tr>
<th>Fumigation Category</th>
<th>Mean Volume (ft³)</th>
<th>Mean Est. Temp. (°F)</th>
<th>Mean Planned Exposure Time (h)</th>
<th>Mean Actual HLT (h)</th>
<th>Target / Actual CT (oz-h/1000 ft³)</th>
<th>Mean Final Dose (lb/1000 ft³)</th>
<th>Mean lb of Fumigant Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Mills &amp; Warehouses</td>
<td>744,500</td>
<td>85</td>
<td>24.2</td>
<td>12.1</td>
<td>451 / 608</td>
<td>3.0</td>
<td>2122</td>
</tr>
<tr>
<td>Rice Mills &amp; Warehouses</td>
<td>1,371,600</td>
<td>85</td>
<td>39.1</td>
<td>15.1</td>
<td>423 / 652</td>
<td>2.1</td>
<td>4255</td>
</tr>
<tr>
<td>Food Processing Plants &amp; Warehouses</td>
<td>1,910,400</td>
<td>82</td>
<td>28.6</td>
<td>15.8</td>
<td>479 / 646</td>
<td>2.2</td>
<td>4060</td>
</tr>
<tr>
<td>Other Mills &amp; Warehouses</td>
<td>2,409,400</td>
<td>79</td>
<td>28.0</td>
<td>16.6</td>
<td>561 / 742</td>
<td>2.9</td>
<td>3403</td>
</tr>
<tr>
<td>All Mills &amp; Warehouses</td>
<td>1,234,400</td>
<td>84</td>
<td>29.8</td>
<td>13.9</td>
<td>449 / 628</td>
<td>2.7</td>
<td>2785</td>
</tr>
<tr>
<td>Commodity Bin, Bin warehouses, Chambers, &amp; Stacks</td>
<td>216,300</td>
<td>74</td>
<td>44.6</td>
<td>43.8</td>
<td>476 / 787</td>
<td>1.7</td>
<td>480</td>
</tr>
</tbody>
</table>

©™Trademark of Dow AgroSciences LLC
ProFume is a Restricted Use Pesticide.
Always read and follow label directions.
96% of the millers surveyed indicated that they would use ProFume™ again for their subsequent fumigation (4% remained undecided)

Fumigator (n = 34) satisfaction ratings averaged 4.4 out of 5

Miller (n = 20) satisfaction ratings (at 60 days post-fumigation) averaged 4.5 out of 5

Survey conducted in 2004-2005; Rating Scale of 1-5, 5 = completely satisfied
# Commercial Acceptance of ProFume®

Structural Fumigations in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>France</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Germany</td>
<td>0</td>
<td>3</td>
<td>16</td>
<td>30</td>
<td>60</td>
<td>109</td>
</tr>
<tr>
<td>Italy</td>
<td>0</td>
<td>2</td>
<td>30</td>
<td>40</td>
<td>80</td>
<td>152</td>
</tr>
<tr>
<td>Spain</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td>15</td>
<td>15</td>
<td>46</td>
</tr>
<tr>
<td>UK</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1</strong></td>
<td><strong>13</strong></td>
<td><strong>58</strong></td>
<td><strong>88</strong></td>
<td><strong>201</strong></td>
<td><strong>361</strong></td>
</tr>
</tbody>
</table>

- The total number of fumigations in Europe more than doubled from 2006 to 2007, indicating commercial acceptance.
Global Commercial Acceptance of ProFume®

- Additional ProFume fumigations conducted in Australia, Trinidad, Mexico, and Mauritius in 2008
  - Example: 2008 ProFume fumigation of Mauritius flour mill
    - Funded from the Multilateral Fund (Montreal); implemented through GTZ (Windhoek) under the direction of the Mauritius Ministry of Environment
    - Insects Limited, Inc., Dow AgroSciences, Hardy Henry Services, and Rentokil International
    - The mill had a 12.9 h HLT and accumulated CT dosage 855 oz-h/1000 ft³
    - The target pests were successfully controlled with no damage to electrical equipment

The mill was previously fumigated with phosphine, which damages sealed electrical equipment.
ProFume® Case Studies: Cocoa

- In the USA, cocoa beans now fumigated with ProFume - collaborative research effort between Dow AgroSciences, cocoa fumigators, and Chocolate Manufacturer’s Association (CMA)
  - Cocoa beans and fractions fumigated at maximum CT dosage rate (1500 oz-h/1000 ft³) with ProFume had a marginal increase in F- that was much lower than the MRLs granted by the USA-EPA
  - CMA conducted sensory evaluations using ProFume-fumigated cocoa - concluded the results are satisfactory
ProFume® Case Studies: Cocoa

- ProFume is more economical than methyl bromide for this use pattern
  - Sorption of SF into cocoa beans is much lower than that of methyl bromide under identical conditions (Phillips et al., Oklahoma State University)

- A commercial efficacy trial demonstrated that ProFume killed the target pests in bioassay (including Indian meal moth eggs) at low temperatures (45°F)
  - 20 h fumigation - Accumulated CT dosage 750 oz-h/1000 ft³

Commercial fumigation of cocoa beans using ProFume

Nearly the entire cocoa industry in the USA has converted to ProFume
ProFume® Case Studies: Seeds

- Dow AgroSciences conducted extensive research evaluating seed of grass, wheat, corn, cotton, soybean and canola in collaboration with three major seed companies.

- Comparative tests were conducted between phosphine and ProFume, under varying exposure periods and temperatures.

- Results concluded that fumigating all tested seed types at 750 oz-h/1000 ft³ did not negatively impact germination or interact with seed treatments, and compared well with phosphine regarding germ impact.
ProFume® Case Studies: Seeds

- Major seed companies in the USA are now adopting ProFume for their seed fumigation
  - ProFume offers flexibility compared to phosphine in reducing the fumigant exposure time, important when seed warehouses are on tight schedules to fumigate seeds prior to shipment
  - All areas of a seed production facility can be fumigated with ProFume, including those with valuable electronic equipment (sizing towers, packaging lines) that could be damaged from phosphine
ProFume® Case Studies: Grain fumigation

- Efficacy on strains of phosphine-resistant red flour beetle, *Tribolium castaneum*, indicated no cross-resistance to SF
  - Resistance issues with ProFume are not anticipated because of use patterns, unique mode of action, and lack of known cross-resistance to other fumigants
- Phosphine-resistant lesser grain borer, *Rhyzopertha dominica*, is widespread globally

Lesser grain borer
(Photo: University of Kentucky)
ProFume® Case Studies: Grain fumigation

- Fumigation of rice and corn in CA have successfully converted from phosphine to ProFume where phosphine-resistant lesser grain borer is present
  - Using a J-fan at the base of the bin and introducing ProFume in the top of the sealed bin results in ProFume dispersing to the bin base, up to 120 ft in 3 h
  - ProFume exposure times average 48-72 h
  - ProFume offers flexibility to rapidly fumigate and aerate grain immediately prior to shipment, reliable control, and the absence of particulate residues
Prior to sale or use of ProFume®, fumigators are required to undergo training

- 3 Major Interrelated Components
- Sign Stewardship Agreement
- Annual Stewardship training required

Classroom Training  Academy Training  Supervised Fumigation
Classroom Training

- Introduction to ProFume®
  - Stewardship Policy

- Labeling
  - Label, Manual & Fumiguide™

- Precautionary Information & Safety/First Aid
  - Connected Areas
  - Security, Posting & Workplace Monitoring
  - Routes of Exposure & Personal Protective Equipment (PPE)
  - Cylinder Handling & Storage

- Dosage Calculation
  - Fumiguide™ Program

- Precision Fumigation™ Concepts
- Fumigation Management Plan (FMP)

- Fumigation Procedures
  - Preparation, Sealing & Set-Up
  - Introduction & Distribution
  - Gas Concentration Monitoring
  - Re-Entry, Managed Aeration & Clearing

- Special Fumigations
  - Surface Ships
  - Stationary Vehicles
  - NAP & VAC Chambers
  - Tarped Stacks
  - Silos & Bins

Trademark of Dow AgroSciences LLC
ProFume is a Restricted Use Pesticide.
Always read and follow label directions.
Academy Training

- Hands-On Site-Specific Applications
  - Pre-Fumigation & Equipment Planning (FMP)
  - Safety, Security, Posting & Workplace Monitoring
  - Preparation & Sealing Procedures
  - Introduction/Equilibrium, Monitoring & Aeration Planning
  - Introduction/Equilibrium, Monitoring & Aeration Equipment Set-Up
  - Introduction & Monitoring Equipment Practice
  - Re-Entry, Managed Aeration & Clearing Procedures
Supervised Fumigation

- Putting it all together on your own
  - Preparation & Sealing
  - Fumiguide™ Model
    - Area-Specific Introduction & Monitoring Set-Up
    - Area-Specific Dose Calculation
    - Monitoring Data Input & Fumigation Status Response
  - Safety, Security, Posting & Workplace Monitoring
  - Re-Entry, Managed Aeration & Clearing
ProFume® Dosages

- Extensive laboratory and field trials conducted to define the dosages required to control all the life stages of target pests under a wide range of fumigation conditions
  - USDA-ARS in California, USA
  - DFA of California, USA
  - Central Science Laboratory (CSL), UK
  - Julius Kuehn Institute, Germany (Formerly BBA, Federal Biological Research Center)
  - University of Milan, Italy
  - Laboratoire National des Denrées Stockées, France

- Dosages implemented in the ProFume Fumiguide™
  - An MS-Windows based program
Dosage calculation tool:
- Based on pest species & desired level of control, temperature, exposure time, volume and half loss time (HLT)
- Gives gas introduction instructions
- When monitoring data are entered, program will calculate actual HLT, accumulated and predicted CT dosage, and update instructions on exposure time and fumigant introduction

- Allows “what if” scenarios to help plan and conduct fumigations
- Enables “Precision Fumigation™” - Takes the guesswork out of fumigation
ProFume® Fumiguide™

- Most recent edition released in Jan 2008
  - Includes new pests, additional temperature calculations, and one-step report generation
- The Fumiguide programmed for a global fumigation market
  - Calculations converted to English or metric units
  - Available in multiple languages
- Records fumigation data and produces reports and graphs

Fumigator uploaded the Fumiguide Report onto the same secure website for customer review as the field-scanned bar-coded data from rodent traps in the customer’s warehouse.
ProFume® Gas Fumigant Summary

- SF, recognized as an excellent wood fumigant for nearly 50 years, has been developed by Dow AgroSciences for commodity fumigation.
- Studies conducted in Europe and the USA have shown ProFume fits the needs of agriculture and food industry for fast and effective fumigation of commodities, food storage, mills and food processing plants with no adverse effect on equipment, food quality and the environment when used according to label.
- Development and commercial launch success in many countries proves that ProFume is a technically and economically viable alternative to methyl bromide, and to phosphine where resistance, damage, or time constraints are issues.