Management of Insects in Stored Grain and Grain-Processing Facilities

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Indian meal moth
Raw grain storage structures

Steel bins

Concrete silos (country elevator)
Insects can infest grain and grain products from the farm to the consumer.
What are stored-grain/product insects?

• Insects associated with cereal grains or commodities that are harvested and stored are called “stored-grain insects”

• These insects are also called “stored-product insects” because they are capable of infesting stored non-cereal commodities and processed cereal or non-cereal products

• These insects have spread throughout the world through grain trade (in ship holds and exports)
### Stored-product insects in the marketing system

<table>
<thead>
<tr>
<th>Type of study</th>
<th>No. samples</th>
<th>No. species</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports into CA</td>
<td>902</td>
<td>37</td>
<td>Olsen (1981)</td>
</tr>
<tr>
<td>Imports in CA</td>
<td>3,381</td>
<td>63</td>
<td>Zimmerman (1990)</td>
</tr>
<tr>
<td>Imports into UK</td>
<td>3,632</td>
<td>81</td>
<td>Howe &amp; Freeman (1981)</td>
</tr>
<tr>
<td>Empty cargo containers</td>
<td>3,001</td>
<td>22</td>
<td>Stanaway et al. (2001)</td>
</tr>
<tr>
<td>Food-handling areas of ships</td>
<td>1,428</td>
<td>16</td>
<td>Evans &amp; Porter (1965)</td>
</tr>
<tr>
<td>Bakeries in CT</td>
<td>290</td>
<td>11</td>
<td>Hankin &amp; Welch (1991)</td>
</tr>
<tr>
<td>Packaged food warehouses</td>
<td>20</td>
<td>24</td>
<td>Highland (1978)</td>
</tr>
<tr>
<td>Import warehouses in CA</td>
<td>18</td>
<td>26</td>
<td>Olsen (1981)</td>
</tr>
</tbody>
</table>

**Source:** Hagstrum and Subramanyam (2006)
Early records of stored-product insects

- Egyptian pyramids, 1345 B.C.
  - Red flour beetle
- Israel, 700-900 B.C.
  - Granary weevil
- Iron Age or Roman Period, 0-400 A.D.
  - Drug store beetle, cadelle, rusty grain beetle, sawtoothed grain beetle, hairy fungus beetle, yellow and dark meal worms
- Mid 1700s
  - Mentioned in literature
Important orders

• Coleoptera or beetles

• Lepidoptera or moths

• Psocoptera or book/bark lice
Development cycle of stored-product insects

Egg
Larva
Pupa
Adult

What are the active stages?

What are the inactive stages?
Cigarette beetle, *Lasioderma serricorne*
Coleoptera: Anobiidae

Photos, courtesy: Dr. Bh. Subramanyam
Development and survival of cigarette beetle life stages on ground, pelleted feed

<table>
<thead>
<tr>
<th>Life stage</th>
<th>No. insects</th>
<th>Duration (days)</th>
<th>Survivala (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>265</td>
<td>8.1 ± 0.05</td>
<td>92.0</td>
</tr>
<tr>
<td>First instar</td>
<td>262</td>
<td>4.7 ± 0.04</td>
<td>98.9</td>
</tr>
<tr>
<td>Second instar</td>
<td>260</td>
<td>4.5 ± 0.04</td>
<td>99.2</td>
</tr>
<tr>
<td>Third instar</td>
<td>259</td>
<td>4.7 ± 0.04</td>
<td>99.6</td>
</tr>
<tr>
<td>Fourth instar</td>
<td>219</td>
<td>11.8 ± 0.2</td>
<td>84.6</td>
</tr>
<tr>
<td>Pupa</td>
<td>210</td>
<td>4.6 ± 0.05</td>
<td>95.9</td>
</tr>
<tr>
<td>Egg-to-adult</td>
<td>209</td>
<td>38.3 ± 0.24</td>
<td>72.6</td>
</tr>
</tbody>
</table>

aSurvival of eggs is based on 288 eggs.

These are larval stages.
Frequency distribution of head capsule width measurements by instar of cigarette beetle

<table>
<thead>
<tr>
<th>Head capsule width (mm)</th>
<th>Number of insects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12</td>
<td>0</td>
</tr>
<tr>
<td>0.18</td>
<td>2</td>
</tr>
<tr>
<td>0.24</td>
<td>4</td>
</tr>
<tr>
<td>0.30</td>
<td>6</td>
</tr>
<tr>
<td>0.36</td>
<td>8</td>
</tr>
<tr>
<td>0.42</td>
<td>10</td>
</tr>
<tr>
<td>0.48</td>
<td>12</td>
</tr>
<tr>
<td>0.54</td>
<td>14</td>
</tr>
<tr>
<td>0.60</td>
<td>16</td>
</tr>
<tr>
<td>0.66</td>
<td>18</td>
</tr>
</tbody>
</table>

4 instars

Larva
Stored-product insects

- Beetles (50 or more species)
- Moths (3 species in U.S.)
  - Indian meal moth
  - Almond moth
  - Angoumois grain moth
- Psocoptera (several species)
Internal feeders

Weevils

Figure 1.—Grain weevils: *Left*, Granary weevil adult; *center*, rice weevil adult; *right*, maize weevil adult.
Immature stages of weevils

Egg
Larva
Pupa
X-ray of wheat kernels showing development of weevil immatures within kernels
Internal feeders

Moth

Borer

Female moth lays egg on grain kernel. The larva emerging from egg gnaws a hole, no larger than a pin prick, through which it enters the kernel.

Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.

The full-grown larva is as long as kernel in which it has eaten out a large cavity.

The pupa is the stage between larva and adult moth.

The moth leaves kernel by round hole shown.

ANGOUMOIS GRAIN MOTH DEVELOPMENT IN WHEAT

Figure 11.—Life cycle of the Angoumois grain moth on wheat.
**Stages of lesser grain borer infestation**

100 adults left in grain for 7 days and then removed
86° F (30°C)

<table>
<thead>
<tr>
<th>Days</th>
<th>0 days</th>
<th>28 days</th>
<th>56 days</th>
<th>76 days</th>
<th>106 days</th>
<th>128 days</th>
</tr>
</thead>
</table>

Source: Edmond L. Bonjour, Oklahoma State University, Stillwater, OK
External feeders

Cigarette beetle

Rusty grain beetle

Larger black flour beetle larvae

Sawtoothed grain beetle

Spider beetle

Develop on broken kernels, grain dust
External feeders - Scavengers

Dermestids
External feeders - Moths

Almond moth

Indianmeal moth

Moth larvae

Moth scales
Mold feeders

Psocids or booklice

Hairy fungus beetle

Mold/cheese mite

Foreign grain beetle

Flourish under humid conditions
Distribution of insect species in the grain mass (Flinn et al. 2009)

- Data from 23 elevators and 513 bins
- Insect distribution varies by month
- More insects are found on the upper grain layers
- Density of lesser grain borer highest in February
Bins with >2 live insects/kg and distance between intervening bins (Flinn et al. 2009)

- Highly infested bins were located near other highly infested bins
- Data from 23 elevators and 513 bins
- Insects move between bins
Proposed origins

• Mostly tropical or subtropical in origin
• Some species were seed feeders; others fed on molds under the tree bark or on rotting animal and plant matter
• Some species still inhabit these areas
• Majority infest habitats provided by humans
Why are insects present: Sources created by humans

- Food-processing facilities
- Spilled grain in fields or on farms
- Grain/flour residues
  - Combines
  - Trucks
  - Wagon beds
  - Bins
  - Under perforated floors
  - Equipment
Features of stored-product insects

• Small
• Highly mobile
• Live in cracks and crevices
• Feed on a wide variety of food products
• High reproductive rates
• Occur in natural or anthropogenic habitats
General biology: Beetles

• Adults can live between 2 months and a year
  – Short-lived and long-lived beetles
• Mate multiple times
• Both adults and larvae cause damage
• Females lay eggs throughout their adult life
General biology: Moths

- Adults live 6-8 days
- Only larvae cause damage
- Eggs by females are laid within 6 days
- May mate 1-3 times
Sources of insects

- **Raw grain**
  - 21, 3 kg wheat samples/railcar were taken from 8 railcars (Perez-Mendoza et al., 2004).
  - 1024 insects were found in 7 of 8 railcars.
  - 3% of insects were found immediately after sample collection.
  - 77.1% were found 7 weeks after sample incubation.

- **Insects outdoors**
- **Re-infestation from insects already in the mill**
Spatial Distribution

*Trogoderma variabile* (warehouse beetle)

*Plodia interpunctella* (Indian meal moth)

Average daily capture rate from 6/7/00 to 10/11/00

Source: Jim Campbell (unpublished data)
Flour mill 1: Inside and outside mill
Allen & Subramanyam, 2004; unpubl. data)

<table>
<thead>
<tr>
<th>Products</th>
<th>Inside traps</th>
<th>Outside traps</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFB</td>
<td>Purple</td>
<td>Yellow</td>
</tr>
<tr>
<td>HFB</td>
<td>Purple</td>
<td>Purple</td>
</tr>
<tr>
<td>CRP</td>
<td>Purple</td>
<td>Purple</td>
</tr>
<tr>
<td>IMM</td>
<td>Blue</td>
<td>Green</td>
</tr>
<tr>
<td>FGB</td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>TRG</td>
<td>Green</td>
<td>Green</td>
</tr>
<tr>
<td>CFB</td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>LGB</td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>Other</td>
<td>Blue</td>
<td>Blue</td>
</tr>
</tbody>
</table>

Percent of total

- Inside trap totals = 216.6 insects
- Outside trap totals = 260.4 insects
- Product totals = 0.34 insects/gram

IMM=Indianmeal moth, RFB=Red flour beetle, HFB=Hairy fungus beetle, RGB=Rusty/flat grain beetle, FGB=Foreign grain beetle, TRG=Warehouse beetle, CFB=Confused flour beetle, LGB=Lesser grain borer, STGB=Sawtoothed grain beetle, CAD=Cadelle
Insects infest product accumulations inside machinery
Infestation of a disused flour mill

“...insect species were widely distributed throughout the premises in considerably greater numbers than previously thought. ...most of these residues were dead stock which would not be moved during the normal operation of the machinery..”

____________________

Source: G. C. Williams (1962)

- 1932 and 1934-35
- 8-ounce samples were collected from 24 elevator boots and other mill streams from 19 flour mills in Kansas, Oklahoma, and Missouri
- 30 species were found
- 99.9% were beetles from 2367 samples collected from 17 mills during 1934-35 (78% were flour beetles)
- Insect numbers were not influenced by seasonal and climatic changes
Rice weevil was predominantly in whole grain

S. oryzae

Number Recovered

Mill Stream

wheat screenings  wheat  1st break  2nd break  3rd break  4th break  5th break  bran  shorts  sizings  1st tailings  1st middling  2nd middling  3rd middling  4th middling  5th middling  low grade flour  clear flour  patent flour  clear flour  patent flour  to sizing roll  to tailing roll  to middling roll
Lesser grain borer was predominantly in whole grain

### R. dominica

<table>
<thead>
<tr>
<th>Mill Stream</th>
<th>Number Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>wheat screenings</td>
<td>0</td>
</tr>
<tr>
<td>wheat</td>
<td>1800</td>
</tr>
<tr>
<td>1st break</td>
<td>1600</td>
</tr>
<tr>
<td>2nd break</td>
<td>1400</td>
</tr>
<tr>
<td>3rd break</td>
<td>1200</td>
</tr>
<tr>
<td>4th break</td>
<td>1000</td>
</tr>
<tr>
<td>5th break</td>
<td>800</td>
</tr>
<tr>
<td>bran</td>
<td>600</td>
</tr>
<tr>
<td>shorts</td>
<td>400</td>
</tr>
<tr>
<td>sizings</td>
<td>200</td>
</tr>
<tr>
<td>1st tailings</td>
<td>100</td>
</tr>
<tr>
<td>1st middling</td>
<td>80</td>
</tr>
<tr>
<td>2nd middling</td>
<td>60</td>
</tr>
<tr>
<td>3rd middling</td>
<td>40</td>
</tr>
<tr>
<td>4th middling</td>
<td>20</td>
</tr>
<tr>
<td>5th middling</td>
<td>10</td>
</tr>
<tr>
<td>low grade flour</td>
<td>5</td>
</tr>
<tr>
<td>clear flour</td>
<td>3</td>
</tr>
<tr>
<td>patent flour</td>
<td>1</td>
</tr>
<tr>
<td>clear flour</td>
<td>1</td>
</tr>
<tr>
<td>patent flour</td>
<td>1</td>
</tr>
<tr>
<td>to sizing roll</td>
<td>1</td>
</tr>
<tr>
<td>to tailing roll</td>
<td>1</td>
</tr>
<tr>
<td>to middling roll</td>
<td>1</td>
</tr>
</tbody>
</table>
Flour beetles were found in all mill streams.
Fig. 3. The intrinsic rate of population increase for *Tribolium castaneum* at 28.5°C and 65% rh. (Data from Leslie and Park, 1949)
KSU pilot flour mill data, June 15 – October 12, 2002
(Importance of sanitation)

<table>
<thead>
<tr>
<th>No. product samples examined</th>
<th>Percentage of samples with insects immediately after sample collection</th>
<th>Percentage of samples with insects after 8 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>439</td>
<td>53.8</td>
<td>80.1</td>
</tr>
</tbody>
</table>

________________________

Damage caused by insects

• Weight loss
• Heating (110°F [43.3°C] or higher)
• Increase in moisture
• Increase in protein content
• Increase in fatty acid content
• Increase in uric acid content
• Structural damage (Cadelle larvae)
• Contamination of raw and processed foods
  ❖ Excreta, cast skins, eggs, body parts
Damage caused by insects (continued)

• Decrease in seed germination
• Distribution of molds from infected to healthy kernels
• Penalties or rejection at time of sale
• Rejection by customers of infested foods
  ❖ Indianmeal moth larvae in pop corn
• Allergic reactions in sensitive people
  ❖ Dermestid hairs (hastisetae)
What is pest management

• Pest is anything “out of place”
• Management as it relates to pest means
  – Keeping pest numbers below damaging levels by using chemical and non-chemical approaches
  – “This suggests that we need not eliminate them, only keep numbers at very low levels”
  – Whether or not pest numbers are at or above damaging levels is based on visual inspection, sampling grain or using traps in food facilities
Management of insects: concepts

– Preventive
  • Tactics applied prior to infestation or when infestation is low (below damaging levels)
  • Cheaper
  • Long-term management

– Responsive
  • Tactics applied when infestation is at or above damaging levels or when a problem with pests is seen
  • Short-term management
  • Re-infestation will occur
  • May be cheaper or expensive depending on method used
Preventive tactics

• Sanitation of empty bins/silos, grain cleaning, and grain-processing facilities
• Application of insecticides to empty storages or to floors of food plants
• Application of insecticides to grain (“grain protectants”)
• Exclusion practices
  – Air curtains
  – Plastic strips
  – Closing doors and windows; sealing gaps in buildings
• Cooling grain
  – Use of aeration by use of fans in bins/silos
  – Grain chilling
Responsive tactics

• Heat
  – Empty storages and grain
  – Grain heat treatment (only in Australia)

• Fumigants
  – For grain and in food plants
  – Most commonly used fumigant on grain is phosphine
  – In food facilities it is sulfuryl fluoride (ProFume) [not registered in India]
Pest management decisions

• Should be based on sampling information
  – To determine if pests are above or below damaging levels

• US standards for grain for live insects/IDK
  – USDA-GIPSA standard for infested wheat, 2 live insects/kg of grain
  – For milling, FDA Defect Action Level of 32 IDK/100 (g)
    {Millers do not like wheat with IDK >6/100 g}

• Without sampling information one commits two errors:
  – Treating unnecessarily (treatment costs go up)
  – Not treating when needed (damage to commodity goes up)
Insect pest levels for grain-processing facilities

• **We have no standards!**

• The only preventive tactic is sanitation (daily, weekly, biweekly, monthly, etc.) of floors and equipment, and screening windows and tightly closing doors

• There are several insect pest management methods, mostly based on chemicals with one method that uses heat
Sampling insects

• Insects can be detected in grain by sampling grain with several devices or by probe traps
• Determining number of insects in a grain sample is useful for making pest management decisions
• As you take more samples you will be able to accurately estimate insect density
• The FGIS [GIPSA] standards of grain sampling may not always be able to accurately determine insect density
Grain bulk

- Static bulks
- Probe sampler
- Spear or trier
Vacuum probe for bulk-stored grain
Pitfall cone trap

- 95 mm x 125 mm cone-shaped with holes
- Very sensitive
- For surface area of the grain bulk
**Probe traps**

- 370 mm x 27 mm
- Funnel and collecting tube
- Can be inserted into the grain bulk
Trap retrieval is critical!
Infestation rates and grain sampling (Hagstrum et al. 2010)

- 1 insect/kg equals 21,600 insects in 800 bushels of wheat in a truck
- A railroad hopper car carrying 3,000 bushels will have 81,000 insects
- With one sample your errors are large
## Probability of detection for insects in stored wheat

<table>
<thead>
<tr>
<th>No. 1-kg samples per 1000 bushels</th>
<th>Mean no. insects per kg of grain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>2</td>
<td>0.04</td>
</tr>
<tr>
<td>5</td>
<td>0.10</td>
</tr>
<tr>
<td>10</td>
<td>0.19</td>
</tr>
<tr>
<td>25</td>
<td>0.42</td>
</tr>
<tr>
<td>100</td>
<td>0.89</td>
</tr>
</tbody>
</table>

*Source: Hagstrum et al. (1991)*
Stored-grain insect management with insecticides

• Clean empty bins and apply an insecticide
  – Kills live insects present

• Clean grain (if possible)

• Apply an insecticide to grain as it is being loaded into a bin
  – Protects grain from infestation
# Insecticides for stored-grain insect management

<table>
<thead>
<tr>
<th>Product</th>
<th>Active ingredient</th>
<th>Rate</th>
<th>Site treated</th>
<th>Grain type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storcide II</td>
<td>Chlorpyrifos-methyl + deltamethrin</td>
<td>3.0 + 0.5</td>
<td>Empty bins, warehouses, stored grain</td>
<td>Wheat, barley, rice, oats, sorghum</td>
</tr>
<tr>
<td>Tempo SC Ultra</td>
<td>β-cyfluthrin</td>
<td>0.01 or 0.02 g/m²</td>
<td>Empty bins</td>
<td></td>
</tr>
<tr>
<td>Actellic 5E</td>
<td>Pirimiphos-methyl</td>
<td>6 - 8</td>
<td>Stored grain</td>
<td>Corn, sorghum</td>
</tr>
<tr>
<td>Centynal</td>
<td>Deltamethrin</td>
<td>0.5</td>
<td>Empty bins, warehouses, stored grain</td>
<td>Wheat, barley, rice, oats, sorghum, corn, rye</td>
</tr>
<tr>
<td>Evercide</td>
<td>Esfenvalerate</td>
<td></td>
<td>Surfaces</td>
<td></td>
</tr>
<tr>
<td>Diasource, Dryacide, Protect-It</td>
<td>Diatomaceous earth (silicon dioxide)</td>
<td>500 - 1000</td>
<td>Empty bins, stored grain</td>
<td>Wheat, barley, rice, oats, sorghum, corn, peas</td>
</tr>
<tr>
<td>Diacon-IGR</td>
<td>S-methoprene</td>
<td>1, 2.5 or 5</td>
<td>Empty bins, stored grain</td>
<td>All stored grains, spices, seeds</td>
</tr>
<tr>
<td>Spinosad (Sensat)</td>
<td>Spinosyns A + D</td>
<td>1</td>
<td>Stored grain</td>
<td>All stored grains, including wheat</td>
</tr>
</tbody>
</table>
• Grain protectants are applied as grain is loaded into bins
• Calibration is essential to deliver right chemical amount based on grain flow through the auger
Grain protectants do not kill insects developing inside because chemicals do not cross the bran layer.

If grain is infested it should be fumigated with phosphine and then treated with a grain protectant.
Hermetic structures for raw grain and finished products
Cocoons™

Having the shape of a cube, impermeable to gases (hermetic), manufactured of white PVC, flexible, UV resistant. Designed for in or outdoor storage, for agricultural and non-agricultural commodities, dry and in bags. Can be installed at any location in minutes. Annual post harvest loss less than 0.25%. Effective life span 10-15 years.

150MT Cocoons Cargill, Philippines

150 MT Cocoons Rwanda
Cocoons in Laos. Grainbank.

Cocoons in Rwanda. Food Security


Cocoons Bayer Philippines. Hybrid Rice.
Vacuum Technology

February 4, 2009
Laboratory Studies with Storage Pests

Hours to Kill 99% ($LT_{99}$) of Eggs at Two Temperatures and Pressures

<table>
<thead>
<tr>
<th></th>
<th>22.5°C</th>
<th>37.5°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indianmeal Moth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 mm</td>
<td>58.0</td>
<td>17.4</td>
</tr>
<tr>
<td>100 mm</td>
<td>96.8</td>
<td>23.0</td>
</tr>
<tr>
<td>Red Flour Beetle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 mm</td>
<td>69.7</td>
<td>11.7</td>
</tr>
<tr>
<td>100 mm</td>
<td>98.1</td>
<td>20.7</td>
</tr>
</tbody>
</table>

Source: Dr. T. W. Phillips
GrainPro Superbag

- Is made of plastic materials which are as close as possible to glass in “permeability”
- Can be made in any size up to a 50 kg bag
- Has an oxygen barrier

[www.grainpro.com](http://www.grainpro.com)
GAS CONCENTRATIONS

Average CO₂ and O₂ concentrations (%) in a GrainPro Cocoon containing 10 tons of Wheat in bags

- **CO₂**
- **O₂**

![Diagram showing changes in CO₂ and O₂ concentrations over time.](image-url)
Purdue Improved Cowpea/Crop Storage (PICS)

- **Triple bagging:** [http://www.ag.purdue.edu/ipia/pics](http://www.ag.purdue.edu/ipia/pics)
- HDPE (80-100 micrometer thick)
- Outer bag made of polypropylene
- 6% oxygen after 5 days

- Cowpea weevils (*Callosobruchus chinensis*) alive for 28 days
- Damage can be expected
- Used by subsistence farmers in Africa
- [https://www.youtube.com/watch?v=_kDFAgPJESM](https://www.youtube.com/watch?v=_kDFAgPJESM)
- PICS and Superbags similar in performance
Murdock and Baoua (2014)
Use of aeration is possible in cold climates. Goal is to turn fans and set the aeration controller based on cold temperatures at night or during fall/winter.

Aeration is done in cycles as temperature cools outside!

Aeration fans run at 1 cubic-foot per minute airflow

Temperature drops gradually during aeration. Below 15 °C (55°F) insects and mold activity are reduced.

Aerated bins

1, 2, and 3 are aeration cycles

Warmer

Cooler
Grain chilling

- Passing chilled air (10-13°C) through the grain mass
- Bring grain temperature to 10-15°C in 2 weeks
- Such chilled grain will take several months to warm up (3 months)
- At these temperatures insects are inactive and do not grow or reproduce
- Cost of chiller is $250,000 or more!
Grain chiller (Granifigor, Germany)
Aluminum Phosphide
Different formulations for different uses

- Tablets
  - 3 g, releases 1 g of phosphine
- Pellets
  - 0.6 g, releases 0.2 g of phosphine
- Sachets
  - 34 g, releases 11 g of phosphine

Linear gas generation until 80%, then the generation becomes nonlinear

Gas release differences among formulations
  - Pellets > tablets > sachets
Phosphine can be used to treat commodities in various storage structures.
Fumigation

Respiratory protection, gas monitoring, aeration after fumigation are important for effective treatment and for personnel and by-stander safety.
Fumigation

• Should be applied by trained personnel
• Sealing of structures is important
• Fumigation does not prevent re-infestation
• Fumigants are less effective on eggs and pupae of insects
• Bad fumigation leads to resistance problems
  – Like most chemicals, use it correctly following all safety and regulatory requirements
  – Resistance is widespread but increasing exposure time kills resistant insects
Treatments for grain-processing facilities

- Fumigant
  - Methyl bromide (MB)

- Heat treatment

- Fumigant
  - Sulfuryl fluoride (SF)

- Not an ozone depleter

- Ozone depleter

- Fumigant
  - Not an ozone depleter
Methyl bromide used since 1940s was implicated as an ozone deplete along with chlorofluorocarbons.

Methyl bromide production and use phased out as of Jan 2005, except for quarantine and pre-shipment at ports.
Grain-processing facilities must find alternatives to methyl bromide
Sulfuryl fluoride is a new fumigant

- It was approved by EPA in January 2004
- It is a non-ozone depleting fumigant
- Total fumigation time is 24 h
- Does not kill all eggs of stored-product insects unless temperature of facility is 30°C or above
Fumigant confinement

Sealing ensures fumigant confinement
Identifying areas of leakage is important
Half-loss time (HLT)

- Time by which you lose 50% of the original fumigant concentration
- Shorter time, more gas loss, higher costs, CT (concentration x time) product may not give commercial kill
- Longer time, more economical, need less to start, better kill of target pests
- Food industry standard, anywhere from 10 to 15 hours
Concentration Decline vs. HLT

Concentration Decline vs. HLT

Leaky facility
Hal Ross Flour Mill-Gas concentration: Sulfuryl Fluoride

HLT \approx 19.7 \text{ hr}
Heat treatment concept: Raising the ambient air temperature of the complete facility, or a part of it, to 122-140°F (50-60°C), and maintaining these temperatures for at least 24 hours.
Heat Can be Used in:

- Bins/silos (less than 6 hours of treatment)
- Whole-facility treatment (24 hours or less)
- Specific rooms (12 hours or less)
- Specific pieces of equipment (6 hours or less)
Crack/crevice spraying
Only in non-food areas
Several chemicals are available for such purpose
Some leave residues on surfaces and act on insects for several weeks; other include
Insect growth regulators (methoprene and pyriproxyfen) to prevent larvae from becoming pupae

http://pesticidepics.org/
Aerosols (fogging) with Methoprene

Atomizing particles to 10 micrometer. Very cheap technology. Used in mills especially in finished packaged products area.

There are several chemicals for this use

Kills exposed insects
Conclusions

• Know your pests
• Know your facility
• Know how sanitation is related to pest activity
• Inspect and monitor pests
• Pest management service provider is NOT a magician
• Get yourself trained and familiar with sanitation and pest management
Thank you