Food Manufacturing, Processing and Storage Integrated Pest Management

When people discuss food processing pest management, discussion usually concerns a crisis point or another area where a problem has erupted and people are trying to solve the problem. Most concerns revolve around concern from governmental and regulatory enforcement actions or consumer complaints. The biggest impediment to improved management and implementation of IPM systems is the prevailing attitude of eradication. While managers of other commodities such as fresh market produce have accepted IPM principles, the food processing and distribution system has not yet accepted the philosophy behind this system.

What is IPM?

IPM is defined as a systematic approach to commodity protection emphasizing increased information for improved decision making to reduce purchased inputs and optimize social, economic and environmental consequences. The IPM concept emphasizes integration of disciplines and control measures into a total management system. Control or management measures include natural enemies, cultural management, temperature and other physical controls, sanitation and pesticides. This system anticipates and prevents pests from reaching damaging levels and improves overall economic and social outcomes. From an economic and ecological standpoint, IPM is based on the "economic threshold" concept that management action is taken only when potential losses due to pest populations exceed costs of controls available to reduce the populations.

Basic changes in management decision-making processes are required to implement an effective IPM program. Food processors and distributors must realize most decisions have consequences far beyond a particular time period and location. Excessive use of management practices such as pesticides may reduce profitability, create potential worker hazards and stimulate pesticide resistance. Keys to implementing IPM include understanding factors that regulate systems, monitoring, maintaining good records and using this information to make sound management decisions.

What regulates storability?

Postharvest systems are regulated by moisture content, temperature, pest access and time that the product is in a susceptible state. Within biological limits, the greater the temperature, moisture content and the time products are in a susceptible condition, the higher the resultant pest population. Management systems must be built around these biological and management factors and their influence on population dynamics.

Moisture Content: Different insect and mold species have different requirements for grain moisture. The rice weevil is limited by its requirements for high grain moisture (>13%), whereas the lesser grain borer can tolerate dry grain. Within limits, the greater the moisture content, the higher population growth. Mold growth normally requires high grain moisture greater than 14-15%. Most processed goods are low in moisture content, and this helps reduce population development.

Temperature: Temperature is the most important regulatory property in processed food storage. Temperatures below 65°F are unfavorable for insects and molds. Likewise, grain temperatures above 95°F are unfavorable for insects. Insects are especially sensitive to high temperature, and high temperatures have been used as a disinfestation and management practices for centuries. From a stored product management viewpoint, keeping insects at sub-optimal temperatures is important to reduce population development and minimize damage and cosmetic concerns. **Table 1** shows the general response to high and low temperature. The interaction of both temperature and time to achieve mortality are obvious. Even relatively low temperatures can be very effective in suppressing insect populations.

Table 1. Response of stored-product insects to temperatures (Fields 1992)

Zone	Temperature (ºF)	Effect
Lethal	122-140 113	Death in minutes Death in hours
Sub-optimum	95 90-95	Development stops Development slows
Optimum	77-90	Maximum rate of development
Sub-optimum	60-77 60-55	Development slows Development stops
Lethal	41-60 0	Death in days Death in minutes

How long will packages have to be in a cool temperature controlled climate? **Table 2** shows several packages and time to get the temperatures to a level where insect mortality will occur.

Table 2. Times for selected commodities to reach 32ºF to ensure insect mortality. All commodities were exposed in a 27 ft^2 freezer filled to capacity.

Commodity	Temperature Setting (ºF)	Time to 32ºF (hrs)	Time to equilibrium
Cornflakes	-14 -5	7 6	30 30
Flour (100 lb)	-14 -5	55 29	160 130
Macaroni (24 lb)	-14 -5	29 18	130 95

A key component is that insects are very durable creatures and, if insects are given time to adjust to changing temperatures, insects will modify their physiology to survive extended periods of harsh temperatures. This is primarily true for cold temperatures. However, if the temperature change is rapid and dramatic (e.g., taking insects from 90°F to 60°F), very high mortality will occur (**Table 3**).

Different insect species have differing tolerances and temperatures that are optimal. Insects most sensitive to cold are red and confused flour beetles. The most cold tolerant are the weevils and the Indianmeal moth. The stage of development can also help insects survive harsh climates. For example, larvae of the lesser grain borer and rice weevil are very cold tolerant, whereas adults of the rusty and red flour beetles are the most cold tolerant.

Table 3. Mean percent mortality of lesser grain borer and rusty grain beetle populations in instantaneous temperature drop from 86°F.

Temperature	Lesser Grain Borer	Rusty Grain Beetle
86°F	10	19
77°F	6	17
68°F	2	2
59°F	2	1
50°F	10	96
43°F	98	95
32°F	100	99

Surrounding conditions have a significant influence on insects. Earlier discussion demonstrated the significant impact commodity moisture could have on population development. Likewise, relative humidity has a significant impact on insect mortality in different temperatures.

Time: Stored grain insects and molds are very predictable and have an exponential growth curve after the product is processed. Managers have the ability to shift this population curve to the right or to the left and the magnitude of the height depending on their sanitation program and the ability to aerate to control temperature.

Access: Most stored product insects can fly and move within and between storage structures. Maintenance sanitation and residual sprays are keys to minimizing residual populations in storage facilities and reducing the population growth of insects. Food warehouse facilities are very attractive to stored product insects and insects will find these facilities. Keeping insect movement to a minimum is a key component to sound management.

Keys to Reduce Access

Carefully inspect all materials entering a warehouse area. This should include raw products, paper materials, packaging or any other material that could transport insects.

Building design: Design storage and processing areas to minimize open areas, unscreened vents and other areas of access.

Screens: Screen all vents, doors and other areas to minimize access. Use fine mesh screens to minimize penetration.

Make sure doors are not left open, and it is preferable to have double doors to minimize migration.

If a significant infestation is found, eliminate the population to prevent spread and modify microclimate to prevent insects from developing significant populations.

Monitoring Tools

The backbone of any management system is effectively sampling pest populations and monitoring grain/product quality. There has been a great deal of excitement regarding new sampling tools that have become available for insect sampling in grains, warehouses and processing facilities. These tools can be pheromone baited or used unbaited. These sampling tools have not been accepted because they are presently uncalibrated and there is no implementation work demonstrating these in commercial situations. In processing industries, trapping systems are of great assistance in detection to maintain low populations of insects.

Key Monitoring Tools

Visual – Visual inspection can be a key to maintain a low population in food processing and food warehouses. Key areas to watch are foods that are high risk:

- Longest in the warehouses
- From a high risk firm
- In an area that is the warmest
- Near access points
- Poor packaging

Visual inspections also have another added benefit – they force personnel to walk through a facility and notice any open packages, improper sanitation and other areas that will attract and allow a population of insects to develop.

Lights – Lights are often an excellent place to begin a facility inspection. Most stored product insects are attracted to lights. If Indianmeal moths or other insects are noticed flying around lights, there is likely a population within the warehouse. Indianmeal moths were often thought to avoid light; however, they are significantly attracted to light and this is a good way to initially sample for Indianmeal moth adults. Replacing incandescent or mercury vapor light with yellow or sodium arc lights at outdoor areas can be effective in reducing the attraction of insects from outside services.

Trap Design and Attractants

For each insect and sampling requirement, the user must decide what kind of trap and if there are needs for attractants.

A pheromone is a chemical attractant released by an insect to affect the behavior of the same species of insect. Two commonly used pheromones for insects are sex and aggregation pheromones.

Sex pheromones are used to facilitate mate location and mating. There are several commercially available sex pheromones for use in traps to improve sampling. Most commonly used is the Indianmeal moth pheromone.

Aggregation pheromones are chemical substances released to attract members of the same species. The most commonly used is the confused flour beetle pheromone.

Food attractants are often used in corrugated traps and have significant advantages because the food attracts all species of food-processing insects. An obvious limitation to the use of food attractant in a food warehouse is the competition with food odors surrounding the traps.

Trap Placement

Trap placement is a key component in managing food processing insects. Placement of traps is dependent upon:

Time of Year – Different times of the year have different temperature profiles within the processing area and warehouse. When temperatures are 90ºF, extensive movement within and around the facility will occur.

Outdoor Use – If outdoor traps are used to measure movement into a facility, the traps should be placed in areas that will not collect extensive amounts of dust but are close to areas of entry.

Number of Traps Per Square Feet – The number of traps required depends on the risk the manager is willing to take, personnel time available and pest level at which the manager wants to maintain the population. A rule of thumb may be one trap per 4,000 to 5,000 square feet. A key part is putting traps in high-risk areas where there have been insect problems before. This practice can prevent buildup and the requirement for extensive insecticide application or fumigation and/or product removal.

Interpreting Trap Catch

There are no hard and fast rules for interpreting trap catch. A better practice may be examining the trends in trap catch and attempting to modify management practices to reduce populations. Insect population grow exponentially, and when outbreaks occur, they are often easy to measure.

Future Applications

With decreased pesticide alternatives and increased regulations, the processing industry will have to begin looking for alternatives to pesticides. These alternatives will have to be based on the ecology of the system with an emphasis on system regulatory mechanisms. Many flourmills are beginning to use heat treatments to manage insect populations. Management options should emphasize available tools such as hot or cold temperature manipulation, improved monitoring systems in processing, increased awareness of sanitation and housekeeping and having well trained personnel throughout the system from acquisition to marketing.

How to Use Insect Traps in a Warehouse

A tool to determine the presence or absence of potentially harmful pest insects is needed where stored commodities are held for extended lengths of time. Pheromone-baited traps are excellent tools for this purpose.

Trapping systems are significant tools to use in an integrated pest management program in warehouses. Pheromone-baited traps can be used in a variety of ways to assist in a warehouse pest management program:

1. Inspection of bagged commodities.
2. Identification of pests or the potential for pest infestation.
3. Determination of the extent of the problem.
4. Evaluation of a particular treatment or control method.

All pheromone-baited traps were not created equal. Traps for moths may act differently than beetle traps (**Figure 1**). One cannot treat all stored-product pests the same when it comes to recommending an effective trapping program. Long-lived insect adults (e.g., flour beetles) tend to be less attracted to pheromone-baited traps than short-lived insect adults. A flour beetle adult that lives for 12 to 18 months does not react as dramatically as an Indianmeal moth adult that may only live in this stage for one to two weeks.

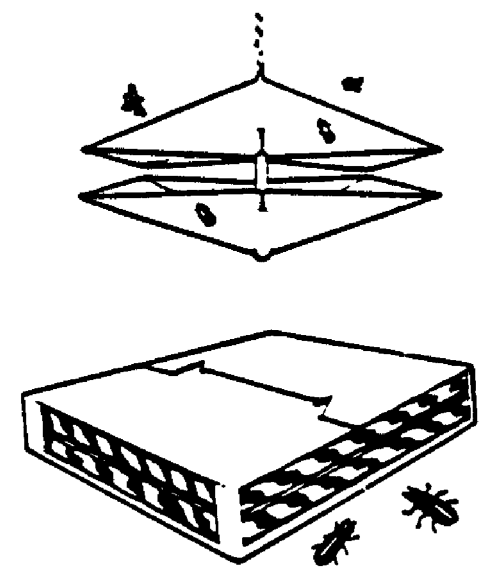

Figure 1. Moth trap (top), beetle trap (bottom).

Know the Pest

Knowing the pest is half the battle in controlling it when establishing and managing a grain, bulk commodity or bagged product pest management program. This holds true when one tries to interpret the results and data from such a trapping program.

Common Insect Pests in Grain and Processed Food

Tables 4 and 5 summarize the results of surveys conducted in 1980 and in 1988 and show the frequency at which stored-product insects were found in raw grain and processed food.

Table 4. Most frequently found stored-product insects in raw grain in the United States.

Rank	Species	Number of States Responding	
		1980	1988
1	Indianmeal moth *	27	30
2	Sawtoothed grain beetle	20	23
3	Red flour beetle*	16	26
4	Rice weevil	19	19
5	Confused flour beetle	17	11
6	Flat grain beetle	7	18
7	Granary weevil	8	13
8	Foreign grain beetle	7	11
9	Lesser grain borer*	8	10
10	Angoumois grain moth*	10	3

* A pheromone lure is commercially available for this stored-product insect pest.

Table 5. Most frequently found insects in processed food in the United States.

Rank	Species	Number of States Responding	
		1980	1988
1	Indianmeal moth *	29	40
2	Sawtoothed grain beetle	33	38
3	Red flour beetle*	24	24
4	Dermestids*	24	23
5	Confused flour beetle*	15	20
6	Cigarette beetle*	13	15
7	Drugstore beetle*	6	11
8	Flat grain beetle	0	3
9	Rice weevil	0	2
10	Granary weevil	0	2
11	Warehouse beetle	0	0

* A pheromone lure is commercially available for this stored-product insect pest.

Traps

It is important to recognize that there is not always one type of trap that is best to use in a pest-monitoring program in warehouses. It is important to match the specific trap to the environmental conditions in each particular situation. Some examples of this would be: 1) dusty areas vs. areas that are not dusty, 2) hot vs. cold temperatures and 3) outdoors vs. indoor use.

Too much dust can cause sticky traps to be ineffective. In this situation, alterations to the sticky trap can prevent an excessive build-up of dust or a pitfall-type trap could be incorporated.

Dusty warehouses offer challenges for conventional sticky glue traps. In these extreme conditions, a sticky trap may become useless after several days, or even after several hours. The selection of a trap that can deflect the dust, or a pitfall-type trap that does not include glue as the entrapment mechanism, will need to be implemented.

Placement of traps will depend on the temperature in the warehouse. In the spring, the ceiling of the unheated warehouse offers optimum conditions for the growth and development of stored-product insects. As the temperature gradients in the warehouse change during the summer months, the harsh conditions near the top of these facilities may hinder the capture of insects in a monitoring program.

Outdoor Trapping

Trapping for stored-product insects around the outside of a stored-product warehouse can offer several advantages in an overall pest management strategy. The trap selected for outdoor trapping must be able to withstand the weather (e.g., plastic construction) and should not be prone to becoming saturated with insects quickly.

By placing pheromone-baited traps on the outer perimeter of a storage facility, potentially destructive insects can be intercepted or lured away from stored food and grain. A feral population of many of the most common stored-product insect pests is available outdoors throughout the United States and Canada. Thus, the outdoor pheromone trapping technique can help the modern pest manager predict the arrival of indoor populations of insects and prevent many from causing an infestation.

Trap Placement

There is no exact number of traps that should be placed in a warehouse to detect the presence or absence of pest insects. The number of traps needed may change according to several factors determined by the trained person implementing and reevaluating a trapping program. Some factors to consider are:

1. Quality assurance standards by management

2. Seed vs. finished goods
3. Pharmaceutical vs. raw intermediate products
4. Popcorn vs. field corn

Important questions to ask are:

1. What is the goal of a sanitation program? Is the goal zero insect tolerance?
2. Is an attempt being made to mass trap out a population, or to just monitor a pest population?

Figure 2 illustrates a situation where one trap per 100,000 cubic feet is placed in a finished grocery product warehouse. The pest management inspector checks each trap weekly. A record of the results is kept in a separate log away from the physical trap itself. A map should be made of each trapping location. Each trap in this practical example contains two lures: (1) *Plodia* complex (Indianmeal moth), and (2) *Trogoderma* complex (warehouse beetle, *T. galbrium,* furniture cabinet beetle, khapra beetle). An optional lure for the cigarette beetle could be placed in each trap in some situations.

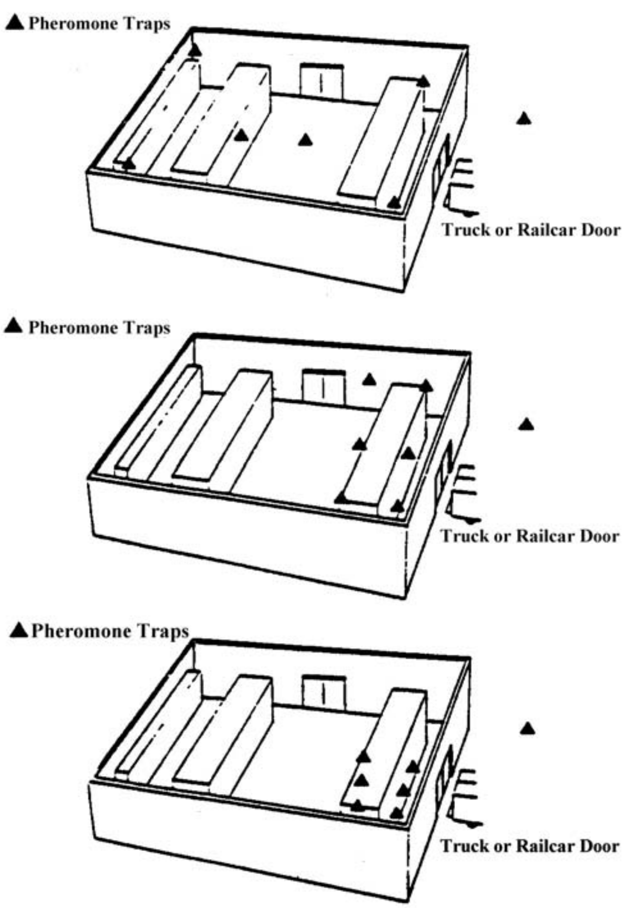

Figure 2. Monitoring for stored-product insects in a finished foods warehouse.

After determining that his warehouse contained little or no detectable target pests in half of the facility, the traps were moved to the half of the warehouse where insects were found in the pheromone-baited traps. Another approach that can be used instead of moving the traps is to employ more traps in a uniform grid pattern in the suspect areas of the warehouse. After several days or a week, these traps are checked and recorded again. At this point, there is one trap per 50,000 cubic feet. If the pest management inspector has more time, he/she can tighten the grid even further to pinpoint this infestation (one trap per 10,000 cubic feet). The inspector can then start visually searching for signs of an active infestation in the areas where the most insects were captured. This could be cast skins of *Trogoderma* larva; odor distinctive to certain insects (e.g., flour beetles and roaches); webbing on bags, flaps of the bags or the surface/side-walls of a grain bin; pupa casing in corrugated cardboard; or actual live insects on finished product.

In this actual warehouse, old code-dated rolled oats were found to be infested with Indianmeal moths, sawtoothed grain beetles and flour beetles. Some nearby dog food also contained large stored-product insects that could have entered this warehouse from the often-opened dock door. The cost of this program for pheromone-baited traps/lures would typically run about $250 to $300 per year. The time needed to count and record seven traps each week would be about 30 minutes.

Interpreting Trap Catch

A common misconception in a strategy used to manage grain, bulk commodities and bagged products using pheromone-baited traps is that there is a set numerical threshold for action or reaction. There is no magic number for determining action. A trained pest management inspector must weigh all factors before making a decision. The key to interpreting trap catch is to look for increases in numbers of insects from one trapping period to the next (e.g., 1 - 5 - 30).

It is often easy to see when an outbreak occurs. At this time, the pest management inspector can recommend appropriate corrective action (e.g., chemical, nonchemical, sanitation, discarding product).

A Plan for Pest Management for the Popcorn and Seed Industry

Purpose: To establish an on-going, year round pest management program to eliminate any damage incurred by insects, rodents or birds. This would include both physical damage to the seed and the defacing of the packaging that contains the seed.

History of the Problem

The popcorn and seed industries in the United States are making rapid advances in the manipulation of the genetic structure of plants in order to create varieties that are more productive. However, even with the amount of technology available, most seed companies are years behind other processed food disciplines in the protection of their stored commodities from stored-product insect pests and rodents.

I. Monitoring and Inspection
- A. Pheromone traps
  1. Indianmeal moth traps
  2. Angoumois grain moth traps
  3. Grain probes in bulk bins
  4. Recordkeeping is essential
  5. Replacement of traps and lures
- B. Glue boards and Ketch-alls/rodent inspection
  1. Dock and loading areas
  2. Critical points in the operation
- C. Visual inspection
  1. Insects
     - a. Inbound packaging materials
     - b. Webbing from moths
  2. Rodents
     - a. Black-light inspections/inbound
     - b. Fecal pellets
  3. Birds
     - a. Nests
     - b. Feces

II. Building to Keep Out Pests
- A. Insects
- B. Rodents
- C. Birds

III. Non-chemical Control
- A. Cold storage
  1. 50ºF with 50 percent R.H.
  2. Insect activity in cold temperatures
     - a. Reduces activity
     - b. No reproduction
- B. Anticipation of winter storage/fumigate before winter
- C. Mice in cold storage
  1. Insulation, be aware
- D. Lighting/placement is critical
  1. Indoors
  2. Outdoors
- E. Beneficial insects (non-food areas)

IV. Chemical Control of Bulk Seed Storage
- A. Timed pyrethrin dispensers *replacing vapona strips
  1. 32-day aerosol cans of two percent natural pyrethrin
  2. Labeled insecticides
- B. Pheromone traps
  1. Moth trap/every fourth bin (outside the bins)
  2. Grain probes in the bins (one per 5,000 bushels)
  3. Check every two weeks/ July-November
  4. Critical check before processing
- C. Routine fumigation of bulk bins
  1. Aluminum phosphine tablets
  2. Aluminum phosphine pellets
  3. New Degesch Mini-Ropes *retains the dust in the rope
- D. Empty bin treatment
  1. Beneficial insects
  2. Residual insecticides
  3. Fumigation: Chloropicrin
- E. Perimeter control
  1. Weeds
  2. Bare ground herbicides
  3. Gravel or blacktop
  4. Insecticides
     - a. Where to spray/one foot upside and two feet away from bin
     - b. How to use/see label instructions
     - c. How often to spray/twice a summer
  5. Spillage clean-up/important

V. Chemical Control in Seed Warehouses and Processing Areas
- A. ULD Treatments (Ultra Low Dosage); *replace vapona
  1. Check pheromone traps/once per week and record catch
  2. Minor threshold: if total catch exceeds 10 moths per week
     - a. Apply remotely if possible (timer)
     - b. Particle size: 15 to 30 micron
  3. Three percent Pyrethrin

4. Types of ULD equipment: Micro-Gen
5. Safety equipment to use
   a. Proper respirators
   b. Draeger detection tubes before re-entry

B. Fumigation with aluminum or magnesium phosphide
   1. Trained, certified and experienced
   2. Safety
   3. Proper storage/cool, dry, well ventilated, locked
   4. Cold temperature fumigation
      a. Magnesium phosphide
         (1) Degesch Fumi-Strip
         (2) Degesch Fumi-Cel
   5. Inert gases
   6. Aerate to safe level
   7. Proper safety equipment available
   8. Draeger detection equipment

VI. Rodent Control Program

A. Outdoor
   1. Bait stations/tamper proof
   2. Rodenticide
      a. Grain based/Talon Weatherbloc, Vengence
      b. Liquid bait, summer
      c. Safety
   3. Building them out

B. Outdoor perimeter control
   1. Weed abatement
   2. Bait stations, every 60 feet
   3. Ditches and standing water
   4. Rats need water every day
   5. Gravel 24 inches perimeter
   6. All doors should fit tightly

VII. Bird Control

A. Cooperative venture with surrounding groups
   1. City
   2. Grain companies

B. Farm machinery sheds

C. Warehouses
   1. Close doors
   2. Plastic strips
   3. Rid-A-Bird perches (restricted use pesticide)
   4. Avicides
   5. Bird netting
   6. Sticky Bird Repellent

Limitations

Pheromone-baited traps have some limitations in management of grain, bulk commodities and bagged products. These traps are very sensitive to the target insects being monitored. However, other insects often are present and go undetected because of a lack of effective or efficient trapping systems. In one field situation, cigarette beetles were extensively monitored and managed with limited applications of chemical insecticides only to find that several pallets of oats were highly infested with a hidden population of flour beetles.

The entomologists' and chemists' inabilities to duplicate the exact chemical messenger or messengers have not given us a complete choice of effective pheromones with which to work. The beetle pheromones seem to be much harder to identify than the moths. However, results demonstrated by the lesser grain borer aggregation pheromone hint that when the components are discovered and mixed in commercial pheromones in the correct combinations, they can work well to detect the presence or absence of a target insect pest. Advances in biotechnology and the potential cloning of these precise chemical messengers will overcome some of these limitations.

Conclusions

The use of pheromone-baited traps to determine the presence or absence of a pest population in storage facilities is an exciting new step toward a total pest management program. The interest in pheromones in recent years has been fueled by their potential to modify the behavior of pests and to attract them to traps. By monitoring the change in trap catch over time in warehouses containing stored products, action levels can be decided and the judicious use of control methods can be prescribed when population growth is observed in one or more areas of a facility.

The practical application of pheromone-baited traps to alter insect behavior and prevent reproduction is helping provide the grain, bulk commodity and bagged product industries with the option of a total pest management strategy.