IPM Manual

Integrated Pest Management

Management Commitment
Key Stored-product Pests
IPM Components
IPM Application for Processes

Developed by the
IAOM Food Protection Committee
September 2016

IAOM
INTERNATIONAL ASSOCIATION
OF OPERATIVE MILLERS

IAOM
Integrated Pest Management Manual

By the International Association of Operative Millers
Food Protection Committee

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About this manual:
This manual was created by the IAOM Food Protection Committee as a special request from the North American Miller's Association to compile a document that would combine information on Integrated Pest Management, particularly due to the phase-out of methyl bromide and concerns with other space fumigants. This manual seeks to provide other avenues of IPM in order to ensure the public of safe food products. The manual was written by members of IAOM's Food Protection Committee who are practical experts in IPM programs, along with additional help from the USDA-Agricultural Research Service (ARS) and Kansas State University with support from independent pest management companies. This manual goes beyond just Milling and Grain processing and can also be used in other food processing industries that handle pest-sensitive ingredients.

Ron Galle
Food Protection Committee Chair 2016

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Chapter 1: Introduction / Management Commitment

Section 1: The Importance of IPM

The goal of Integrated Pest Management (IPM) is to identify, prevent, and eliminate conditions that could promote or sustain a pest population with a food manufacturing, storage, or transportation operation. IPM relies on appropriate assessment, monitoring, and management of pest activities.

A Written Program

A written IPM program is important to the food manufacturer in many ways. First and foremost, the written program sets forth a standard of how the manufacturer will manage the programs necessary to minimize the potential of pests from becoming an adulterant in the foods being produced. The program is also necessary for regulatory, customer, and audit requirements in order to demonstrate the measures taken for an effective program.

The components of this IPM program are derived from the individual facilities assessment. This assessment should cover all areas inside and outside of the facility and evaluate the historical data, conditions, practices and other factors affecting the IPM program. This assessment should be conducted by trained internal or external IPM personnel prior to establishing the IPM program. It should be performed on an annual basis and at any other time where a pest population has compromised or has the potential to affect the safety of the products being produced. The assessment will help in determining what pest prevention measures are necessary for the specific operation. This will help to justify decisions such as trap placement, numbers of traps, frequency of service, etc. The results and corrective actions of all assessments should be documented and used to develop and update the IPM program.

An IPM program relies on well-established, prerequisite food safety programs such as self-inspection, preventative maintenance, building equipment and design, sanitation, etc. Each of these programs supports the overall mission of an IPM program in the area of identification, prevention, and elimination. Specific details of these programs can be found in later chapters of this manual.

Program Administration

IPM programs must be administered by trained, registered, and/or licensed in-house or contracted pest management providers. Product manufacturers should determine the specific Federal, State, and/or local requirements of these personnel when using their products. The requirements will vary depending on the types of services provided or pesticides utilized as part of the service.

The IPM program should state the responsibilities of both in-house and contracted personnel who will be administering the program activities. Communication between in-house and contracted personnel is key to a successful IPM program. Contracted personnel should be updated on the various pest issues or other conditions prior to each visit. This may be communicated directly or by a pest sighting log. Plant personnel are encouraged to keep a pest sighting log current and to direct the efforts of the contracted personnel. The contracted personnel should keep the in-house personnel current of their findings. An example of this may

be a damaged door seal noted by the pest contractor. This contractor should be required to follow-up with in-house personnel through the preventative maintenance program.
Contracts should be established between the pest control providers and the facility to hold both parties accountable for effective pest management activities. The contract should include items such as:

- Facility name
- Facility contact person
- Frequency of services
- Description of contracted services and how they will be completed
- Term of the contract
- Equipment and material storage specifications
- List of approved chemicals, prior to use
- Emergency call procedures (when, why, whom to call)
- Service records to be maintained and length of time
- Requirement to notify facility of any changes in service or materials used

The following sections will provide more in-depth explanations of IPM.

Chapter 1: Introduction / Management Commitment

Section 2: Management Commitment: Key to Success

Establishing and maintaining an effective food safety program for a company is essential in today's food manufacturing environment. Recalls and food safety issues have been in the news media and on consumer's minds all too often. In order to reduce the potential for failure in producing a safe and wholesome product, management must be fully committed to a food safety culture within their organization.

The food industry has undergone significant change in the last several years and even decades. Companies are continually pushed by regulatory, customer, and consumer demands to provide a safe, wholesome product at the most cost effective price possible. These demands have put stresses on organization resources. The milling industry is not immune to these demands and also has its own unique challenges. Let's look at a few.

Challenges Faced by Today's Milling Industry

Capital

Economic conditions and the challenge to produce a cost effective product have never been more significant. Often times, a capital improvement project must show a reduction in people or hours within the workforce or saving money in other ways (*i.e.*, increased productivity). Productivity is important, but can often be in direct conflict with food safety goals. When there is a reduction of workforce or available people hours, sanitation efforts can be one of the first programs to be impacted. As we know, sanitation is a critical component to the success of any IPM program. Every decision for reduction of people hours should be carefully considered to determine how sanitation may be impacted. If equipment, buildings, or grounds are cleaned less often, in less detail, or not as thoroughly, this can create an environment conducive to pest populations. Sanitation is pest control! Management must have a clear understanding of how a reduction in staffing will impact the overall sanitation program.

Qualified Personnel

Through the years, much of the milling industry has lost one specific organizational position, and that is the Sanitation Manager or Plant Sanitarian. These critical personnel were responsible for coordinating the efforts of personnel to maintain a clean mill and address pest related concerns. While the reason why this position has been eliminated varies and it does not mean that this was an incorrect decision, it can be a double-edged sword as neglecting this critical work should lead to food adulteration issues. Also, there are typically no designated positions specific to a sanitarian within the operation. Sanitation responsibilities have been moved into the area of production personnel. This system of sanitation in today's mills can be accomplished and effective, but it does highlight the importance of management having a clear understanding of how sanitation is an important function and must be a part of their employee's job description and daily activities.

The other challenge faced by today's milling industry is the pool of people that are qualified to conduct production activities and who have a proper background and training for food safety, IPM, and sanitation. Since most of these activities have been pushed to production operators, management must clearly define the qualities of an individual being selected for the various positions within the organization. Once these individuals are selected, management must communicate their role to maintain the overall food safety level. A culture must be created and maintained by management and emphasized to all persons.

Time

Production vs. sanitation time can be a significant challenge for the milling industry. Often times, downtime is simply viewed as a loss of profit. So, how does management view downtime within the operation? Downtime is very limited in the milling industry and there are several items to be completed during this downtime. Mill repair is often one of the most significant needs during this time. In order to keep some equipment operating effectively and efficiently, it can only be repaired during a shutdown. The question for management will be, "Where does sanitation fit into this downtime?" Managers must be aware of the needs for sanitation while scheduling activities during a shutdown.

- What items will need to be cleaned?
- Are there any pest related issues that need to be addressed?
- Who will conduct the sanitation activities?
- Who will coordinate sanitation and maintenance of equipment that needs to be disassembled for effective sanitation?
- Who will evaluate the level and effectiveness of this sanitation?

These are some of the many related questions management will need to consider while scheduling downtime. As mentioned earlier, commitment to a food safety culture will need to be on the minds of management during these activities.
Some of the challenges affecting food safety have been outlined here, so what are the solutions?

Culture

A food safety culture starts at the top of any organization. This may be a vice president of operations, but also must be the Plant Manager on site. Management must be actively involved and spearhead the efforts in order to drive this culture. Management needs to be a leader in the area of food safety and ensure that all departments and persons recognize their significance and impact to a food safety program. Without this direction, daily demands of operating a mill can quickly overshadow the need to balance decisions and review the impact of those decisions on the food safety program.

One of the ways to establish and maintain a food safety culture is by developing a food safety team. This team should be multi-disciplinary and its main goal is the production of a safe product. By having a food safety team with leaders from various departments, focus can be placed on those factors that may impact product safety. This also highlights the importance of everyone's activities and their role in the food safety program. Consideration should be given to meeting on a regular frequency to review food safety related issues within the operation. One of the best ways to identify these possible issues would be to utilize this team to conduct regular, thorough inspections of the mill focusing on food safety and pest management. These inspections will be discussed in a later chapter.

Monitoring and Planning

Foresight, planning, perseverance, and close identification with staff and customers are big factors in a successful business operation. For those involved in food product safety, the function of monitoring includes knowledge of new and current laws, knowledge of consumer attitudes, and knowledge of the most efficient ways to clean and sanitize the facility and equipment. At the time of this writing, all three of the above-mentioned items were rapidly changing. The Food Safety Modernization Act is being implemented and will have a significant impact on the regulations affecting the industry. Consumer attitudes are at a very high level in regards to food safety. Awareness of food safety problems to the consumer has grown and will continue to grow with today's attention by the media, sharing of food safety problems in the social media, recalls, etc. Today's technology for cleaning is also rapidly progressing for reasons such as the reduction in pesticide use, allergen and microbiological concerns, and customer demands. Management must stay current on the most effective and efficient ways to clean and maintain their facility.

Planning is the function of management that makes things happen that otherwise would not have happened. As discussed above, management should be aware of and monitor changes that are happening within their facilities and the entire milling industry. Once aware of those changes, management must plan accordingly to implement programs and systems. Of course, food safety should be one of those significant events to be planned for. The food safety team is an important component in the planning process and can make these events happen within the facility. Management must stress the importance of these events and ensure they are completed in a timely manner. Scheduling specific activities should be carefully considered and the impact of delay evaluated. What may seem simple, such as delaying a sanitation task, may allow insects to complete a life cycle and quickly become an infestation issue, leading to customer complaints, a potential recall, damage to the company's brand, and large negative financial implications.

Organizing and Staffing

These two functions are so closely related as to be inseparable in many departments. In order to be effective, an organization has to be complete, with the ultimate, attainable goal of cohesiveness among all departments and individuals.

One rule of an organization that cannot be overemphasized is the hiring of competent people in all positions. The relative level of ability may vary from person to person or department to department, but each individual must be able to perform with all the skills required to get the job done right the first time. As stated earlier, management must ensure that all employees are aware of their role in the food safety culture. An example of this may be looking at candidates to fill a position in maintenance. This individual must understand and be willing to conduct food safety related tasks within his or her normal duties. This may include cleaning equipment after maintenance repairs, keeping work areas neat and orderly, being able to identify food safety issues while servicing equipment, and recognizing conditions that may lead to pest harborage, etc.

It is not enough to simply hire competent individuals. They must also be retained. Management should give these individuals challenging responsibilities, involve them in planning decisions, regard them as associates rather than subordinates, and provide them with the opportunity to elevate themselves. To foster the food safety culture, these individuals should be recognized when they have gone above and beyond their normal duties and have identified and/or addressed a food safety concern. This may be as simple as recognizing them among their peers or providing a small benefit such as a gift card.

Staffing is a systematic involvement of people, the process of relating individual jobs to the total purpose of the organization. Each employee must be able to identify with and strive toward certain goals both short and long range. Every position should be more than a simple job description; it should have a clear objective within the context of company operations. Management and employees should have a mutual understanding of what those objectives are. When it comes to actual staffing for completion of tasks such as sanitation and integrated pest management (IPM), management may need to be creative. To address the issue of people hours, some companies have chosen to train persons from other departments and make them cross-functional in the area of sanitation and IPM. From a cost standpoint, some companies have found it less expensive to pay overtime wages for persons to complete sanitation and IPM tasks vs. additional downtime for the mill. However your organization chooses to complete such tasks, involving and challenging your employees can help foster the food safety culture.

Measuring (controls)

Measuring is a function that is very close to planning. In planning, a department says what it is going to do. In measuring, the department reviews its performance regularly and monitors and verifies where it stands at the moment compared to its ultimate goal. Once a goal has been reached, it must reevaluate its position, and the entire process begins all over again. Good measures must meet three requirements: They must be prompt, meaningful, and economical. Looking specifically at sanitation and IPM, management must have systems and methods to measure their performance. One way to measure sanitation and IPM would be to evaluate customer complaints for items such as insects, foreign materials, mold, etc. Obviously, this is not a preferred method of monitoring performance of the company's food safety goals. Proactive measures such as self-inspections, employee suggestions, IPM inspections, verification of completed tasks, etc. can provide effective data in measuring the food safety level of the organization.

Other

The heading of "Other" may not sound very exciting or be specific, but there are many other requirements of management to maintain this system of a food safety culture and support IPM within the organization. One of the simplest ways to convey what these "other" items are is to refer to the entire IPM manual. There are many "other" categories in the guide and each should be reviewed and understood.

It is important to understand why this IPM manual was developed. The milling industry identified a need to provide a tool for companies to utilize in furthering their efforts in the area of IPM. IPM's ultimate goal is to manage pests throughout the production of food to prevent them from becoming an adulterant, introducing contaminants, causing economic damage to the product or facilities, etc.

Management must recognize the importance of their daily decisions and how they may impact the IPM program. One example of this would be looking at the sanitary design of equipment, whether it is a new piece of equipment or if modification and upgrades are being made to existing equipment. The design of the equipment will ultimately impact whether the equipment can be easily cleaned and maintained to keep it free of pests or other food safety related hazards. Unless management recognizes the importance of sanitary design and drives the process from sourcing to installation, this will not happen.

In conclusion, management commitment to a food safety culture is the key to producing a safe product. It is imperative that management be committed to understanding and executing the goals and "other" components of an IPM system. Food safety does not simply happen; it is a way of life that only management can champion and foster within the organization.

Chapter 1: Introduction / Management Commitment

Section 3: Regulatory Compliance (DAL, Pesticide Usage/Registration)

It is important to understand various regulations that impact IPM. These regulations range from broad food safety regulations such as the Food, Drug and Cosmetic Act, Food Safety Modernization Act and Good Manufacturing Practices, to specific regulations covering pesticide registration, pesticide usage, applicator licensing, and defect action levels within the United States. For those companies operating outside of the United States, some countries/regions have specific food safety regulations with which they should be familiar. Examples of these would include:

- Food Standards Australia New Zealand (FSANZ) Act of 1991 – Australia/New Zealand
- The Food and Drugs Act – Canada
- Food and Drug Regulations – Canada
- Technical Regulation RTCA 67.01.33.66 – Central America
- Regulation (EC) 852/2004 – European Community
- Food Safety Basic Law – Japan
- Food Sanitation Law – Japan
- Technical Regulation GMC No. 80/96
- Mexican Official Norm NOM-120-SSA1-1994
- Food Hygiene Law of the People's Republic of China – People's Republic of China
- Sans 10049:2001 Food Hygiene Management – South Africa
- The Food Hygiene (England) Regulations 2006 – United Kingdom

Where there are no region-specific regulations, internationally developed and recognized standards such as The Codex Alimentarius Commission Food Hygiene Basic Texts (2003) may be used as guidance for developing prerequisite and food safety programs.

The regulations listed above drive regulated standards, but the food industry changes very quickly, and often the regulatory process takes time to catch up. New advances related to the production of safe food are being developed continuously. As the food industry learns about new food safety issues and processes, innovation becomes part of food safety practice. In fact, some large companies create their own standards that are even tougher than the regulations demand.

For purposes of this chapter, we will focus on three major regulations that pertain specifically to U.S. food manufacturers and to food companies around the world as a whole. First, the Food, Drug and Cosmetic Act was passed by the FDA in 1938 which provides identity and quality standards for food. There are two main sections to this Act.

a. 402 (a)(3) - A food shall be deemed adulterated "if it consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food; or"

b. 402 a(4) - A food shall be considered adulterated "if it has been prepared, packaged or held under insanitary conditions whereby there is reason to believe it has become contaminated with filth or whereby there is reason to believe it has been rendered injurious to health". SAHCODHA (Serious Adverse Health Consequences or Death to Humans and Animals) When the FDA identifies this condition, they have reason to believe there is potential health hazard associated with that product.

In the most simplistic form, 402(a)(3) says a food is deemed adulterated if it contains a material that is not on the label. This may range from harmful contamination such as biological, chemical and physical, to those adulterants that may not harm a person or animal such as insects, filth or other materials. It is the responsibility of food companies to ensure they have programs and systems to prevent and detect such adulterants. A mill producing a product with insects in the finished product would be in violation of this law.

The FDA recognized that 402(a)(3) did not cover all potential food safety issues that Congress passed 402(a)(4) in the 1960's. The challenge the FDA faced was inspecting a facility that had significant food safety issues in the manufacturing environment, but not being able to find adulteration in the food product. This section means that it is also a violation of the law for a mill to be producing a finished product with infestation, roof leaks, flaking paint, leaking lubricants, or other contaminants which "may" adulterate the finished product. This section gave the FDA much broader authority to hold a food facility accountable for the condition of the overall facility. The FDA does not have to find a contaminant or adulterant in the food product, but to simply identify those conditions which may contaminate the product.

In order to understand what conditions should be managed within a food operation, the Good Manufacturing Practices were then written to define them. The GMP's are part of the Code of Federal Regulations in 21CFR part 117. Managers of a food operation should fully read, understand, and evaluate how the GMP's apply to their operation. The GMP's establish the criteria under which the law is applied and are the guidelines that companies should follow to create plant policies and procedures.

The main sections of the GMP's that require specific programs and policies to manage possible food safety risk are Personnel, Plant and Grounds, Sanitary Operations, Sanitary Facilities and Controls, Equipment and Utensils, Processes and Controls, and Warehousing and Distribution. The current GMPs are available from the FDA website at http://www.fda.gov/Food/GuidanceRegulation/CGMP/ucm2006830.htm.

The final and most significant change to food safety regulations within the United States that will also have an impact on all companies exporting to the U.S. is the Food Safety Modernization Act (FSMA). This law is the most sweeping change to food safety regulations since the Food, Drug and Cosmetics Act.

There are various reasons as to why this law was passed, but the most significant was the number of food recalls, the threat to public health, and the limited oversight of imports and foreign suppliers, etc. FSMA provides the Food and Drug Administration with greater authority to enforce regulation and broader access to records. This is a great example as to why it is imperative for a food company to understand the regulations and what programs and policies are necessary to produce a safe food product. The FSMA website is available at http://www.fda.gov/Food/GuidanceRegulation/FSMA/default.htm

The key provisions of FSMA are:

- Evaluate hazards and implement preventive controls
- Direct (FDA) food facility re-inspection and food recalls
- Supplement goals of National Agriculture and Food Defense Strategy
- Identify preventive programs and practices to promote the safety and security of food
- Maintain sanitary food transportation practices
- Manage food allergens
- Direct (FDA) and establish food testing laboratory accreditation program
- Initiate foreign supplier verification activities
- Create a voluntary qualified importer program to expedite review and entry of foods
- Inspect foreign facilities registered to import food

The impact of FSMA on IPM has yet to be determined. Some of these key provisions will require food companies to re-evaluate their systems and programs to ensure they meet the requirements of FSMA. Specific FSMA rules have been/will be published by FDA on a roll-out basis of specific sections of the law. However, we do know that IPM is an important component of FSMA. Specifically, IPM will be a key element in the hazard assessment and preventive controls.

All food companies should identify a department and person(s) that will be responsible for ensuring compliance with various FSMA/food safety regulations impacting their operations. It is important that this person(s) and department remain current on food safety regulations and determine what, if any, changes are necessary in their operation. However, managing this, and any food safety requirement, is a 24 hour/7 day a week job and should not be burdened on the shoulders of a few individuals or departments in a food company. Making safe food is a company-wide requirement and involves the constant interaction and communication between many individuals. Management commitment is key and food safety starts with the CEO!

A plant must have a trained individual to manage food safety programs. The FDA has determined what the criteria would be for this person within FSMA. Specific definitions of such have been given. Definitely, a basic knowledge of HACCP and food safety programs will be needed.

One cannot begin to explain FSMA within this chapter. It is recommended that the law be read by going to the FDA FSMA website referenced above.

Chapter 1: Introduction/Management Commitment

Section 4: Customer Considerations

One of the primary goals of Integrated Pest Management is to provide customers with a wholesome, regulatory compliant, and food safe product. A properly managed IPM program will take into consideration and eliminate or reduce to an acceptable level anything (originating from storage pests) that would negatively impact customer relations. This section will outline the components needed to put into place a pest management program that will ensure minimal risk of negatively impacting customer relations from a storage pest related incident.

Customer expectations, beyond expecting that all ingredient functionality-related specifications are met, are typically focused on wholesomeness of the ingredients and raw materials being supplied to them. An ingredient cannot be considered *wholesome* (generally defined as: suggestive of health or well-being, particularly in appearance) if it does not meet the customer's expectations in reference to storage pest- related contamination levels. Additionally, customers expect that wholesomeness to be maintained through the end of the ingredient's prescribed shelf-life, one aspect of customer satisfaction that has a strong potential of being negatively impacted by a less than adequate IPM program.

Tolerance Levels

Contamination from storage pests can create conditions in milled grain products that range from completely harmless (aesthetic) to pathogenic and potentially a threat to human or animal health. Though the latter can only occur in extreme situations under just the right (or wrong) conditions, the possibility needs to be considered. Establishing a target level of zero is not only impractical, but is virtually unachievable given that nearly all milled grain products are derived from raw materials that are exposed to "the elements" throughout their growing cycle.

In an effort to set maximum allowable amounts of these naturally occurring contaminants in milled grain products, the FDA has established "tolerance levels" outlined by the Food Drug and Cosmetic Act of 1938, http://www.fda.gov/RegulatoryInformation/Legislation/FederalFoodDrugandCosmeticActFDCAct/default.htm. Food product that exceeds these established levels is considered "adulterated" and is not legal to sell for human consumption. Customers typically expect raw materials to be, at a minimum, in compliance with government regulations. In some instances, a customer's internal specifications may be even more stringent than the regulatory levels.

Many food manufacturing companies employ some level of incoming raw material sampling and analysis. Materials found to be adulterated according to regulatory tolerance levels, upon delivery, may result in a number of difficulties for the ingredient or food product supplier. It is the ingredient or food product manufacturer's responsibility to ensure regulatory compliance of their product prior to sale and delivery to their customer. To this end, it is recommended that the manufacturer have in place a strong IPM program coupled with a finished product testing program based on risk-analysis that includes testing for levels of potential pest contamination.

Under current federal regulations, any food ingredient, primary food packaging or food processing aid that comes in contact with a food product must be in compliance with FDA tolerance levels or be subject to recall and reporting to the FDA Reportable Foods Registry. This information then becomes public knowledge and may hold several negative implications for the raw material manufacturer, the finished product manufacturer and for the customer of either. These tolerance levels apply to foreign materials at the macroscopic (*i.e.*, insect parts), microscopic (*i.e.*, Salmonella) and molecular level (*i.e.*, pesticide chemical residue). See the chapter on Regulatory Compliance for additional information.

Food Safety

The increase in numbers of companies being certified to a Global Food Safety Initiative (GFSI), http://www.mygfsi.com/, suggests stronger emphasis being placed on food safety. This applies to all levels of food product manufacturing and has resulted in a higher level of communication, implementation of more well-defined food safety programs, and a stronger requirement for sharing information about food safety programs than ever before. The general tendency is to require that the responsibility for providing a food-safe finished product be shared by all levels involved in the manufacture and delivery of that finished product to the consumer. Pest Management is a key requirement of all schemes currently recognized by the Global Food Safety Initiative.

Either due to requirements under the GFSI certification or simply in accordance with a customer's company policies, many companies are now insisting that ingredient or raw material suppliers and finished product suppliers meet a set of pre-determined requirements prior to being approved as a supplier. Typically, an IPM program and the supporting programs, procedures and policies are included in these requirements. These requirements, in addition to the basic IPM Program, may include:

- Implementation of monitoring, trend analysis and corrective actions associated with pest management/ pest activity
- Positive Release Program (holding product for test results) / Hold & Release procedures
- Policies for corrective action for customer complaints or non-compliant test results
- Trace & Recall Program/ Product Recovery Plan (RFR logic)
- The supplier's own "Supplier/ Raw Material Monitoring" program

Often, information pertaining to the existence of an IPM Program and the supporting programs is requested by a customer as part of a supplier approval process. This information can be requested according to varying levels of detail. Some customers request this information via a one-time questionnaire while other customers may conduct an actual on-site audit of programs, records and facilities and repeat this process at a set frequency or as a result of an incident.

If the customer has implemented a supplier monitoring program, the customer may require an annual sharing of information, further visits to the supplier's location and/or notification of non-conformances discovered by other means (*i.e.*, outside lab testing) even if it is discovered prior to a product being shipped. According to many customers' programs, discovery of non-compliance (typically an exceeded tolerance level or the existence of actual pest activity) in a raw material or finished product upon or after being delivered to the customer can result in a lengthy investigation. The cost of investigating the incident and any costs associated with returning/recovering product are typically passed along to the supplier. The outcome of the investigation could result in a probationary period, a temporary suspension, or termination of a supplier's "approved" status.

Summary

A well-implemented and successful IPM Program can be an integral part of maintaining good customer relations and avoiding cost and complications. Failure of an IPM program can result in customer complaints, rejection of product, supply chain interruption, and possible loss of market share. The cost of poor quality due to this type of an incident can include damage to the name/ reputation of the supplier and, possibly, to the customer, and may even result in litigation or a lawsuit. It is obviously in the best interest of the milling establishment to keep the customer in mind when establishing food safety regulations.

Chapter 2

Key Stored-Product Insect Pests

Chapter 2: Key Stored-Product Insect Pests

Section 1: Introduction to Stored-Product Insects

A wide range of insects can be found in and around food facilities such as flour mills, rice mills, and food and feed production facilities. Some of these insects are obligatory pests that are attracted to stored food, and live and breed in the food product. These are the stored-product pest insects. Other insects found may be opportunistic species that can be attracted to stored food and inhabit buildings, but generally do not live in the grain or flour (for example, cockroaches, flies, ground beetles, and ants) or incidental pests that generally don't persist inside grain or inside mills and warehouses, but may be attracted into a structure by lights, warm temperatures, or moisture. Natural enemies include predatory or parasitic insects that feed on pest insects, but don't feed on the stored-products. These insects are commonly found inside and outside food facilities. Any insect found inside a mill or warehouse indicates a problem, the nature of the problem, and the potential risk it poses. The best management tactic varies with the insect species.

More than 1,660 insect species have been reported to be associated with stored-products (Hagstrum and Subramanyam, 2009). Fortunately, only a relatively small proportion of these species have characteristics that make them significant pests of a particular grain and grain-based product. Each facility tends to have a unique set of species (community) that commonly occur at that site. The species composition of this community is based on factors such as commodities and ingredients that are present at the site, geographic location, and the surrounding environment. In mills, this insect community may be relatively consistent from year-to-year, but in facilities with a lot of inbound and outbound products, such as warehouses and distribution centers, the insect community may vary widely over time. Proper identification of insects found in a facility is critical, because once a species is identified, information on its biology can be used to assess risk, identify likely sources, and guide pest management decisions.

Stored-product insect populations increase only if supplied with favorable conditions. The growth and development of all stored-product insects is dependent upon temperature, relative humidity, and the availability of food resources. In general, optimum development occurs when temperatures are in the range of 75-90°F (24-32°C), and with most species favoring between 80-90°F (27-32°C). Most stored-product beetles take about 6 weeks to go from egg to adult at 80°F (27°C), while moth species take 3-4 weeks to complete development at this temperature. These development times will vary with temperature, diet, and other biological and environmental factors. Growth is slowed as temperatures increase above 100°F (38°C), and above 120°F (49°C), death begins to occur. As temperatures approach 60°F (16°C), population development will generally cease, but insects will not die until temperatures drop below freezing. Temperature also influences insect behavior, with insects able to fly generally when temperatures are greater than 77°F (25°C), and walking activity decreases with decreasing temperatures. This relationship with behavior impacts the ability to detect presence of pests, especially adults, using traps.

There are many publications available that provide more extensive coverage of stored-product insect identification, biology and management that can be used to help guide pest management programs: for example, Gorham (1991a), Subramanyam and Hagstrum (2000), Rees (2004), Hagstrum and Subramanyam (2008), and Hagstrum et al. (2012). A list of some online stored-product insect resources is also available.

Chapter 2: Key Stored-Product Insect Pests

Section 2: Types of Stored-Product Insects

Insects are animals that have an external skeleton (exoskeleton), three body sections (head, thorax, and abdomen), three pairs of legs, typically two pairs of wings in the adult stage, compound eyes, and antennae. Most stored-product insect pests are either beetles (Coleoptera) or moths (Lepidoptera), although there are exceptions, such as psocids, that don't fall in these two groups. Beetles and moths all have what is called complete development, meaning that they have four developmental stages that differ in appearance and behavior: egg, larva (feeding stage), pupa (transformative stage that does not feed), and adult (reproductive stage, which may or may not feed). Identification of stored-product insects is typically based on examining the adult stages, although there are some keys to identify larvae of some stored-product insects.

Adult moths are characterized by having two pairs of wings covered with scales, which can be detached from the wings. If adults have mouthparts, they consist of a long tube for drinking, but they do not having chewing mouth parts and do not feed on grain or grain products. Only the larval stage of moths causes damage to stored products. Most stored-product moths are relatively small and drab in color. Color markings on adult moths come from their scales, but since these can be rubbed off with age or activity, another simpler character can be used to identify a moth species. Different moth species have different types of labial (lower lip) palps. Moth larvae typically have a hard head capsule and a soft body with three pairs of jointed legs which are true legs near the front of the body. Moth larvae often have additional structures that look like legs (termed prolegs), but are not jointed like true legs. The prolegs can be used to determine if a larva is a moth or a beetle species, but in some moth species, these prolegs can be reduced in size and hard to see. Stored-product moths can be challenging to identify to species in the egg, larval, or pupal stages.

The beetles are the largest order of insects, are very diverse, and exploit many types of environments. Beetles have biting and chewing mouth parts and in most species of stored-product pests, both the adults and the larvae can feed. The pronotum is the top portion of the first segment of the thorax, and in beetles it is extended to cover the whole thorax. Characteristics of the pronotum are sometimes used in identification of beetles. Beetles have the first of their two pairs of wings modified to form a hard cover (elytra) for the second pair of wings. The front pair of wings are not used for flying, but offer protection for the hindwings that are membranous and used for flying. The lifespan of an adult beetle can be highly variable, with some species living a week and some species more than a year. Most stored-product beetles are brown to black in color and are relatively small. Beetle larvae can vary in appearance and are generally difficult to identify to species. Beetle larvae generally have three pairs of legs, although these can be missing in some species and do not have prolegs like moth larvae.

Another way to group stored-product insects is based on their type of feeding. Only a limited number of stored-product pests are able to feed on intact kernels of grain. These are considered primary pests of grain. With these species, typically most of the immature stages occur within the grain kernels. These are the species that are most damaging to the grain and cause insect-damaged kernels (IDK). Many other species can only cause limited damage to whole kernels and are considered secondary pests in grain since they feed primarily on broken kernels, dockage, or kernels damaged by primary insect pests. These species become more important after the grain is milled or processed. Another group of stored-product insects are the fungal feeders; these feed on fungi (mold) associated with moist grain and grain products (≥14.5% moisture, wet basis). Many stored-product insects are opportunistic feeders and can infest a wide range of foods including spices, dried fruit and vegetables, nuts, beans, oil seeds, processed foods, animal feeds, pet foods, and dry animal products (e.g., dried fish. Lists of stored-product insects and the foods and products they are associated with have been published (Hagstrum and Subramanyam, 2009; Hagstrum et al. 2013).

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Section 3: Identification

There is quite a bit of information available on identification of stored-product insects, much of it is very technical. There are also simpler approaches using pictures and key physical characteristics that can be used in many cases to identify major pest species or groups of species. However, caution is needed when identifying stored-product insects since many are small and similar in appearance to each other and to other non-stored-product insects. Misidentification of insects recovered within food facilities or captured in traps is common.

Accurate identification to species typically involves using a dichotomous key to identify the insects – this process uses a series of steps where two choices of physical characteristics are presented, and by moving through these questions, the range of options of potential species becomes narrower until a particular species or group is the only one left. Using many of these keys requires some familiarity with insect morphology and magnification to be able to see the small features used for identification. Adults are usually the stage that can be most easily identified, with larvae of many species being more challenging to identify, and eggs and pupae even more difficult.

Sometimes the best course for insect identification is to send the insects to an expert, such as a pest management professional, extension agent, or a university or government entomologist. When saving or sending insects for identification, it is important to preserve them – hard-bodied insects such as adult beetles and moths can be stored dry, but soft-bodied stages will shrivel up when dried, making identification more difficult. Storing in ethyl or isopropyl alcohol will help preserve the insects until they can be identified. Sticking the insects under tape is not a good way to save or ship insects for identification; it is better to place them in a small, hard-sided container or vial. Including some tissue or other soft paper to prevent the insects from being banged around during shipping can help preserve them. Sometimes insects can be identified, at least tentatively, by sending high quality photographs to an expert. Photos at a high magnification and from multiple angles will be most useful.

There are many keys available to help with identification of stored product insects and they vary in their focus, level of technical knowledge required, and resolution in identification. The book *Insect and Mite Pests in Food, Volumes 1 and 2* by Richard Gorham (1991b) is very comprehensive with many line drawings of insects and detailed keys. Another book that focuses on the beetle pests is *Beetles Associated with Stored Products in Canada: an Identification Guide* by Bousquet. Another useful guide with illustrations and keys is *Insects and Arachnids of Tropical Stored Products: Their Biology and Identification – A Training Manual* (Dobie et al., 1991). The book *Insects of Stored Products* by Rees (2004) in addition to dichotomous keys to help guide identification includes many high quality photographs, key characters to help with identification, and information on biology and management. Some relatively simple pictorial keys to some of the common pest species are available online (*e.g.*, USDA ARS ID Stored Wheat Insects. Other websites have good summaries of morphological features and pictures along with general information on the biology and damage caused (for example, Canadian Grain Commission website. Hagstrum and Subramanyam (2009) provide an extensive list of published and online keys available for stored-product insects. Hagstrum et al. (2013) has high quality photographs of adults of more than 200 stored-product insects, with notes on hosts attacked, geographic distribution, references to biology, and information on pest status.

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Section 4: Insect Species Associated with Stored Products

In bulk stored wheat (metal bins, concrete elevators, flat storages, railcars), the most commonly found primary pest species are beetles, the lesser grain borer being most prevalent, followed less frequently by rice weevils and granary weevils. The lesser grain borer becomes less prevalent and damaging at northern latitudes. The predominant secondary feeders are the flat grain beetle, rusty grain beetle, red flour beetle, confused flour beetle, and sawtoothed grain beetle. Two moth species are commonly found in bulk grain, although typically just near the grain surface: Indianmeal moth and almond moth. Two fungal feeders are also commonly found associated with bulk stored grain, the foreign grain beetle and hairy fungus beetle. Reproduction of fungal feeders in bins is typically associated with moisture problems, but adults are good fliers and can readily move into and out of bins from outside sources. These same species can be associated with grain in bins during spring and fall in the Midwest, and in railcars and other transportation carriers.

In grain-processing facilities, the most commonly found species and typically the species with highest risk of product infestation is the red flour beetle. In some mills, the confused flour beetle may be more abundant and, in some rare cases, both species may co-occur in the same mill. Other species that are commonly recovered inside mills, although their ability to successfully establish and cause infestations varies, are the warehouse beetle, Indianmeal moth, rusty grain beetle, cigarette beetle, sawtoothed grain beetle, and a variety of fungus feeding beetles. Large numbers of warehouse beetles are found outside of grain-processing facilities, especially during the summer months. In warehouses and retail environments, the Indianmeal moth is the most commonly found insect species. The diversity of species found in mills and warehouses is often related to the ability of insects to enter these structures from the outside through gaps in the building or through openings near doors and windows. Fewer stored-product insects were reported from grain-processing facilities that are cleaned regularly to remove accumulated food products or spillage. Generally, the greater the diversity of ingredients in a facility, the greater the potential diversity of stored-product insects. As many as 30-100 different species of stored-product insects have been reported from flour mills, feed mills, warehouses, and retail stores.

Outside of bulk storage bins and around food facilities, a wide range of stored-product species can be captured; some may be dispersing from other structures and others may be exploiting spillage accumulations outside. In general, fungal feeding species are more prevalent outside. The warehouse beetle and the Indian meal moth are widely distributed and commonly found in high numbers outside. At some locations, particularly more southern locations, the almond moth or Mediterranean flour moth may be an abundant moth species. Also around bulk grain storage locations, the lesser grain borer and *Sitophilus* species (rice, maize, or granary weevils) may be very abundant. There can also be a large and diverse community of insects outside that can enter a facility, storage bin, railcar, or truck.

The species listed above and presented in more detail below are those that are most commonly found and that have wide spread distributions. However, each facility tends to have a unique community of stored-product insects. In addition to the commonly found insects, a given facility may have other stored-product insect species that become established and increase in numbers, becoming a local problem. Recognizing this new species is important in assessing risk and formulating the best management response. Because many of these other less globally important species are similar in appearance to the major pest species, they are often misidentified. This can also lead to mistakes in management response. This is why proper insect identification is essential for good pest management. Short descriptions of some of the predominant stored-product insect species are given below, and additional information is summarized in Table 1.

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Section 5: Major Stored-Product Pest Species

Lesser grain borer, *Rhyzopertha dominica*

This species is a major primary pest species in stored grain, and since both adults and larvae feed it can be highly damaging. It is in the family Bostrychidae (not Bostrichidae), which includes primarily wood borers. The larger grain borer, *Prostephanus truncatus*, is also in this family and is an important grain pest in South and Central America and in East and West Africa, but it is not typically found in North America. The lesser grain borer has a world-wide distribution, but is less prevalent and damaging in northern latitudes, probably due to its poor adaptation to cooler grain temperatures. Lesser grain borer species is most likely associated with bulk stored whole grains such as wheat, corn, rice, and sorghum.

Adults have a relatively unique morphology among the stored-product beetles, so are relatively easy to identify. Adults are brown-black beetles about 0.1 in (2.5 mm) long with a cylindrical or bullet shaped body with many small pits on the elytra (wing covers). When looking from above the head is not visible since it is pointing downward and is covered by the pronotum. The antennae are club shaped, with the club made up of three loosely connected segments. Adults are the only developmental stage that is typically seen, since other than the eggs and newly hatched larvae which are very small, all the other life stages are normally found inside the grain kernel. Larvae found inside grain kernels can be separated from the other likely species based on the presence of three pairs of fully functional legs. The other species of larvae commonly found in grain will have no legs (*Sitophilus* weevils) or reduced legs (Angoumois grain moth).

Lesser grain borer is a strong flyer, typically flight occurs around dawn and dusk, and they can rapidly colonize stored grain. It can also feed on acorns and be found in wooded environments that may serve as a reservoir from which they can move into newly-stored grain after harvest and binning. Both male and female adults tunnel through grain kernels. A female can lay anywhere from 300-400 eggs during its lifetime. Females lay an average of 10 eggs per day. When the larvae hatch they bore into kernels or enter through natural fissures, where they complete development to the adult stage inside the grain kernel. The adult will then bore out of the kernel, creating a round exit hole. Wheat kernels with these holes are called insect-damaged kernels (IDK), and wheat with 32 IDK per 100 g is considered sample grade and cannot be used for processing into food. Identification of lesser grain borer feeding damage can be based on fragmented kernels, powdery residues, and a characteristic fruity odor. Adults of these species can be monitored using pheromone-baited traps placed outside the grain. Probe traps in the grain mass can capture moving adults, but because the adults are slow moving, trap catch tends to under-represent the number of beetles present. A better way to sample lesser grain borer adults in grain is to take grain samples of known weight (typically 1 kg or 2.2 lb) using a grain trier or a pneumatic probe.

Rice weevil, *Sitophilus oryzae*, maize weevil, *S. zeamais*, and granary weevil, *S. granarius*

Weevils belong to the family Curculionidae, and contain a large number of pest species, three of which are commonly found pests that damage grain. These weevils are primary feeders on whole kernels of grain, and despite their names all three species can be found feeding on a wide range of grain types. While typically found with whole grains, they can also be found feeding on beans, nuts, processed grain such as pasta, birdseed, and pet food. All three species have a worldwide distribution, but certain species may be more abundant in different geographic regions. For example, granary weevils are less common in tropical areas, where rice and maize weevils are better able to compete. In the U.S., rice and maize weevils appear to be the most abundant species.

Adults have a unique appearance that makes them relatively easy to identify as weevils and to separate from other stored-product pests: the head has a long snout that has the mouthparts on the end and elbow shaped antennae. This snout is unique to the weevils, but there are many weevil species, most of which are not stored-product pests and might be incidental species that are not damaging to the stored grain. Adult weevils are brown to almost black in color and between 0.1-0.2 in (2.5-5 mm) in length, but size can vary considerably depending on the size of the grain in which they develop. Granary weevils can be separated from the rice and maize weevils based on oval shaped indentations on the pronotum and a uniform coloration (no patterning on elytra). The rice and maize weevils have a pronotum with round indentations and also tend to be darker and to have orange or yellowish spots on the elytra. The density of pits in maize weevils are greater than in rice weevils. However, the rice and maize weevils are morphologically very similar and cannot be reliably separated from each other without resorting to dissection. Fortunately, these two weevil species have similar biology and management so it is typically not necessary to identify them further. Another important difference is that the granary weevil does not fly and lacks flight wings under the elytra, while the rice and maize weevil do fly and have flight wings under the elytra. However, they are generally considered to be weak flyers. Adults are typically the only developmental stage easily observed, since eggs, larvae, and pupae are found inside kernels of grain. If larvae are found inside kernels and they lack any visible legs, they are likely to be a *Sitophilus* species.

Adult granary weevils rely on walking for dispersal, and infestations often are initiated by human transportation of the weevils, while maize and rice weevils can fly, so they are more capable of dispersing and actively colonizing stored grain. At wheat storage locations, weevils tend to be more abundant in spillage than in the bulk stored grain. Females chew oviposition holes into grain kernels and deposit eggs singly in these holes and the fill them with an egg plug. These egg plugs can be seen under magnification if observed carefully, and staining methods are available to aid in identifying infested kernels. Adults can live for up to six months and females can lay a large number of eggs over their lifetime. Both larvae and adults feed on kernels and cause damage. Damage can appear different from the lesser grain borer, since adults cause small, round holes when feeding, and emergence holes tend to be larger circles with ragged edges. However, both weevil and lesser grain borer adults will feed in damaged kernels, expanding openings and both groups can cause IDK. Pheromone lures are not widely available for *Sitophilus* species, but food attractant-baited traps can be useful for monitoring activity outside of bins. Adults can be monitored in grain using probe traps.

Angoumois grain moth, *Sitotroga cerealella*

This moth in the family Gelechiidae is one of the few moth species that can be a primary grain pest, since it has the ability to penetrate and develop within whole grain kernels. The biology of this moth is similar to that of the lesser grain borer, the eggs are laid outside of kernels and the newly hatched larvae enter kernels to complete development to adulthood. Adults emerge from kernel through a round hole (IDK). Angoumois grain moths occur around the world, but primarily in geographic areas with mild temperatures and especially in the tropics. In the U.S., this species is common in the southern states. While this species can attack a wide range of grains, it is most commonly associated with stored corn and rice in the U.S. This species is reported to infest grain in the field and especially in tropical areas this can be a major source of infestation. While most commonly associated with whole grains, they are also reported infesting dried plant materials.

Adults of this moth are relatively unique compared to other stored-product moths. With a fresh adult that has not lost many scales, they are a greyish brown color with a small, black spot on the first pair of wings. These are relatively small moths (0.20-0.24 in, 5-6 mm) long, with the first pair of wings coming to a point and the second pair of wings having a long fringe of hairs along the back edge. Antennae on the adults are relatively long and often you can see what looks like a second set of antennae but are really mouth parts (labial palps). Larvae are not typically seen since they occur inside the grain. Because of this behavior, the larvae of these moths are different from other stored-product moths in that they have short, reduced true legs and prolegs. This makes them easy to confuse with beetle larvae.

Adults do not feed, are short lived, and are active typically at dusk and in the dark. Females lay eggs in cracks and crevices and when they hatch the larvae chew into the grain kernels. The rest of development takes place inside the kernels and when ready to form a pupae, the larvae chews an emergence hole that is covered with a window made of silk. After adults emerge inside the grain kernel, they exit through this window. Damage is typical to that of other internal feeds because they cause IDK, but when adults emerge from grain, part of the pupal case can often be found sticking out of the round emergence hole. Traps baited with pheromone lures can be effective for monitoring this species and adults moving in the grain can be captured in probe traps.

Sawtoothed grain beetle, *Oryzaephilus surinamensis*, and merchant grain beetle, *Oryzaephilus mercator*

These beetles are in the family Silvanidae, which mostly contains species that live under the bark of trees where they feed primarily on mold and detritus. There are other species within this family that can be stored-product pests, but are typically have a lower pest status and are often associated with degrading grain where they feed on mold. The sawtoothed grain beetle and merchant grain beetle are both important stored-product pests and attack a wide range of grain and grain products, as well as nuts, spices, oil seeds, and dried fruit. Both of these species have a world-wide distribution and are found in the U.S. in both bulk storage grain, where they are a secondary pest exploiting damaged grain, but in mills, food processing, and processed food storage facilities they can be a highly damaging pest. Because of their size and behavior they are very good at invading packaged food materials.

Adult beetles in this family are characterized as small (0.1-0.15 in, 2.5-3.5 mm), flattened with parallel sides, and having projections from the sides or corners of the pronotum. Both the sawtoothed grain beetle and the merchant grain beetle have saw tooth like projections along the sides and three ridges along the tops of their pronotums. These two species look very similar to each other, but can be separated using magnification to see differences in the length of head behind the eye. If it is relatively short (eye close to the back of the head) then it is the sawtoothed grain beetle and if it is relatively long it is the merchant grain beetle. Larvae and pupae can be found outside of grain.

The sawtoothed grain beetle is more likely to be found in grain and grain products, while the merchant grain beetle is more commonly found in dried fruit and oilseeds, although this is not a hard and fast rule. Adults can live a long time, months to years, and continue to feed. Adults of many species in this family can fly, as can the merchant grain beetle, but the sawtoothed grain beetle does not fly. Adult sawtoothed grain beetles are very active, however, and walk considerable distances in a short period of time. Females start to lay eggs within a week after emergence as an adult and can lay hundreds of eggs during their life. Eggs are laid singly and primarily in crevices in food. Larvae are external feeders and don't have distinctive features that make them easy to identify. Before pupation, a larva will build a pupal cell and fasten itself to a solid object. Both the larva and adult stages feed, but do not cause a characteristic type of damage. They are secondary pests in whole grain, exploiting damaged grain, but can cause contamination issues in food facilities and in processed and packaged foods. Because of their size and shape, adults can enter through small openings, and flaws in packaging, and female sawtoothed grain beetles have even been observed to lay eggs through openings that they are too small to enter themselves.

Rusty grain beetle, *Cryptolestes ferrugineous,* and flat grain beetle, *Cryptolestes pusillus*

These two species are in the family Laemophloeidae (formally Cucujidae) which contains some important stored-product pests, but most species in the family live under the bark of trees. The genus *Cryptolestes* has nine species that are known to be stored product pests, but these two - species are the most widely distributed and damaging in North America. The rusty grain beetle has good cold tolerance and often becomes a more important pest in northern regions of the US and in Canada. Found primarily on whole grains, especially wheat, and milled products, it can also be found exploiting a wider range of other foods such as nuts, cocoa, and cassava under tropical conditions. The rusty grain beetle can often occur in high numbers in stored grains carried over from one year to the next. The flat grain beetle tends to be the more dominate species under tropical conditions, and has similar characteristics regarding grain infestation and damage as the rusty grain beetle.

These species in this genus have features that make them relatively easy to separate from other stored-product beetles. As adults they are small (0.1 in, 2.5 mm, long), flattened, parallel-sided, reddish in color, and have very long, beaded antennae. Compared to most other beetles, the head and thorax are large and together they encompass half the body length. Although the genus is distinct, it is difficult to separate the different species within the *Cryptolestes* from each other without dissecting the beetles.

Adults are long lived and can feed. Eggs are deposited in crevices and cracks in grain or loosely in the food, and larvae feed externally in the grain. Larvae prefer the germ, but will also feed on the endosperm of the kernels. Small larvae will sometimes tunnel into small cracks in kernels as they feed. Rusty grain beetled do not develop well in very dry grain. Larvae, when ready to pupate, form a silk cocoon inside kernels or between kernels. Larvae and adults both feed, but damage is generally not specific. The larvae and adults can also be cannibalistic on eggs and pupae. These insects can be readily monitored using pitfall traps in the grain because they are highly mobile. Pheromone lures are not available for these species, but they can be monitored outside of grain using traps with food attractants.

Red flour beetle, *Tribolium castaneum*, and confused flour beetle, *Tribolium confusum*

Although a large number of beetle species in the family Tenebrionidae are stored-product pests, the red flour beetle and confused flour beetle are the most widespread and economically important species. However, since many of these other species are similar in appearance to these two species, it important to be aware of some of these other species. Some other species commonly found include the larger black flour beetle (*Cynaeus angustus*), longheaded flour beetle (*Latheticus oryzae*), American black flour beetle (*Tribolium audax*), black flour beetle (*Tribolium madens*), and dark flour beetle (*Tribolium destructor*). The red flour beetle is one of the most commonly found species in stored products, and in addition to feeding on grain and grain-based products, can exploit a wide range of dried animal and plant materials. Red flour beetles are also predators of other insects, scavengers and cannibalistic. Both red flour beetles and confused flour beetles have a worldwide distribution and are major pests of mills. Historically, confused flour beetles were more commonly found in mills, but most recent surveys of mills in the U.S. primarily find the red flour beetle. The confused flour beetle has also been reported to be more common in cooler climates than the red flour beetle, but inside heated structures this may no longer be the case.

Adult beetles are reddish-brown in color and measure 0.12-0.20 in, 3-5 mm, in length with small indentations on the pronotum. The red flour beetle and confused flour beetle are similar in appearance, but the red flour beetle has the last three segments of the antenna forming a club. The gap between the eyes, when looking at the underside of the head, is narrow and the confused flour beetle has last three segments gradually widening, and a wide gap between the eyes. These differences can be difficult to identify without some practice, but given differences in behavior and susceptibility to insecticides it is important to know which of the two species is present in a given facility. The larvae are external feeders and are active, but morphologically can be difficult to separate from other beetle species.

These beetles can on whole grains, although they prefer broken and damaged kernels. In whole grains the adults tend to feed on the germ, and the egg-to-adult development is longer on whole grains compared to development in flour and flour products. They are most damaging to flour and other milled products. Eggs are laid loosely in food material and typically become coated in flour or other fine particles. Adults of both species have developed wings, but the red flour beetle flies and the confused flour beetle does not fly. Adult *Tribolium* can live for more than a year, and females can lay eggs for several months under laboratory conditions. Both species can tolerate high temperatures and low relative humidity. Both species can be monitored using pheromone-baited traps targeting walking individuals and can be monitored in grain using probe traps.

Pyralid moths, Indianmeal moth, *Plodia interpunctella*, Mediterranean flour moth, *Ephestia kuehniella*, almond moth, *Cadra cautella*, and others

These moths have a worldwide distribution and feed on a wide variety of grain and grain-products as well as other seeds, nuts, dried fruits, chocolate, and spices and can be important pests, especially in processed foods. The Indianmeal moth is one of the most damaging stored-product moths for the grain-processing industry, retail stores, and homeowners. The other moth species in the family can be important stored-product pests at a given facility, but tend to have a more limited distribution in North America.

Adults are small moths, typically less than 1 in (25 mm) wing span, with moth parts upturned and facing forward. Wing scale color patterns can be used to identify the adult moths, but this requires relatively new adults with intact scales. Indianmeal moth adults are relatively easy to identify since they have a distinct color pattern to the wings: part of the wing closest to the body is a light cream color and the outer part of the wing is copper brownish in color. Mediterranean flour moths have forewings that are light grey in color with black markings that can be crosswise-lines and spots, and hindwings that are a dirty white. Almond moths, also sometimes called the tropical warehouse moth, are also grey to brown in color with a dark straight band across the forewing. Larvae have typical caterpillar characteristics and are difficult to identify to species. Mediterranean flour moth and almond moth larvae are cream to pink in color and have two black spots in each body segment that run in a parallel line down the back. Indian meal moth larvae are normally pale cream in color, but depending on the foods they are consuming, they can be different colors such as pink or green.

Adults are typically nocturnal and with peak flight activity at dusk and a smaller peak at dawn. During the day adults are typically found resting on vertical surfaces. Adults do not feed and are very short lived (1-2 weeks), but females can lay a large number of eggs during this short time period. Eggs are laid in food and newly hatched larvae can be effective at entering flaws in packaged food. Larvae are external feeders in whole grain, feeding primarily on broken and damaged kernels and the germ and bran layer of whole kernels, but they do best on milled grain and processed foods. Larvae produce silk as they move in the food material and the presence of webbing that binds pieces of food material together will be an indicator of moth infestation. Prior to pupating, the larvae have a wandering phase where they can leave the food and find sheltered places to pupate. Pupation occurs inside a silk cocoon, which are often found in small openings such as in corrugated cardboard and peg board. When temperature decreases and the day length shortens, larvae can also enter diapause, a state of suspended development, to overwinter. Adult males can be detected and monitored using pheromone baited traps, and the same pheromone lure can be used to monitor Indianmeal moths, Mediterranean flour moths, almond moths, raisin moths (*Cadra figulilella*) and tobacco moths (*Ephestia elutella*).

Cigarette Beetle, *Lasioderma serricorne*, and drugstore beetle, *Stegobium paniceum*.

Cigarette beetles and drugstores beetle are found worldwide, although the drugstore beetle is more commonly found in temperate regions and the cigarette beetle in tropical regions. In temperate regions of the world, they overwinter inside warm structures. Despite their names, both species can be serious pests in a wide range of commodities, not just tobacco or pharmaceutical/medicinal plant products. Both can also be found infesting grain and grain products, dried fruits, dry pet foods, processed human foods, coffee, chocolate, nuts, spices, and herbs.

Adults are small, (0.08-0.16 in, 2-4 mm in length), tan-colored beetles with a hump shaped appearance. They are covered in fine hairs, so on close inspection they appear fuzzy. Adults have long antennae and in the cigarette beetles they are thin and saw-like, and in the drugstore beetle the outermost sections are enlarged forming a loose club shape. The elytra of both species is covered with fine hairs, but the adult drugstore beetle also has a series of lines (striae) created by longitudinal rows of pits. Larvae are cream colored with a brownish head, have fully formed legs, are covered in long hairs, and have a scarab larvae type of shape (similar to the "c"-shaped grubs of Japanese beetle and other species often found when digging in lawns).

Adults are short-lived and while they do not feed, they can chew holes in packaging and other materials. Adults are strong flyers and are typically active at dusk and early evening. When adults are disturbed they pretend to be dead and curl up and remain motionless for long periods time. Neither species is considered a major pest of grain, but both can be very important pests of processed commodities including pet foods and spices. Females lay eggs in crevices and larvae tend to tunnel into food and become less active and more c-shaped as they develop. In solid foods, a characteristic of infestation is that the material can become riddled with tunnels. Small larvae can enter small holes in packaging and larger larvae and adults can chew through many types of packaging materials. Larvae make cocoons from food and waste in which they pupate. Adults can be monitored using pheromone and food baited traps and light traps that attract both males and females.

Warehouse beetle, *Trogoderma variable*, and khapra beetle, *Trogoderma granarium*.

Dermestids are a large group of beetles, most of which feed on dried animal material, and are often found in bird and animal nests or feeding on dead animals. Warehouse beetles and khapra beetles are the two major stored-product pest species in this family, although there are a number of other species that are similar in appearance that can be found associated with human structures. The warehouse beetle is a generalist feeder and can feed on a variety of foods, but is primarily a pest in processed foods, particularly those with a high protein content. It is a major pest of the pet food industry. Warehouse beetle is widely distributed primarily within the northern hemisphere. The khapra beetle is one of the most destructive pests of grain in the parts of the world where it occurs, but it is not currently found in North America. It is the only quarantine stored-product pest in the United States, and is frequently detected in imported materials. Khapra beetles feed on a wide range of stored products, but unlike other dermestids they prefer whole grain and cereal products to animal-based products and are a major pest of grain and oilseeds in hot dry climates.

Typical of dermestid beetles, adult warehouse beetles are oval shaped and covered with fine hairs. They are typically dark brown in color with the elytra marked with variable wavy patterns of lighter yellowish to reddish areas. Khapra beetles are similarly shaped but tend to be lighter in color and to lack the patterning on the wings. Accurate identification of any dermestid beetle to species can be challenging given the similarity among species and variation in color, pattern, and size within a species. Many other species can be found associated with food facilities, some of which may be incidentals and others that may be other potentially damaging species.

Larvae of dermestids beetles are also vary distinctive, but difficult to identify to species. The larvae are vary in color, tending to be white or yellow early get darker reddish brown with age, and have bands of hairs along their bodies and tufts of barbed hairs on the end of the abdomen. Warehouse beetle adults are short lived and egg laying peaks after a few days and then rapidly declines. Adult khapra beetles are short lived, do not require food or water, and most eggs are laid during the first few days of the oviposition period. Eggs are laid singly either loosely or in crevices. Adult warehouse beetles are strong fliers and commonly found outside of food facilities were they can disperse considerable distances. In contrast, the khapra beetle does not fly and relies on human transportation. Nevertheless, it is still a potentially dangerous invasive species should it become established in the United States. Eggs are laid in the food material and larvae are external feeders. Larvae are generalist feeders and do not cause distinctive damage, but caste larval cuticles will accumulate in and around infestations and are a good indicator of their presence. The hairs on the larvae and their cast larval cuticles can cause gastrointestinal irritation and allergic reactions for some individuals. Larvae can penetrate most packaging materials and are a serious pest of packaged foods. Because of their broad host range, they can also be found associated with rodent baits and can feed on the dead insects and animals that can accumulate as part of a pest management program. Larvae may enter a form of diapause when the environment is unsuitable, where they continue to feed and molt intermittently, but do not pupate, and this diapause can be maintained for over 6 years with intermittent feeding. This behavior, particularly for khapra beetles, contributes to their ability to persist in structures and to be transported long distances. It also makes them difficult to manage since they are less susceptible to fumigation and other insecticide treatments in this state. Pheromone baited traps can be used to monitor warehouse beetles. The khapra beetle will respond to the same pheromone lures as the warehouse beetle. Since khapra beetles do not fly, traps targeting walking beetles are needed for monitoring this species, although walking beetle traps also work well for warehouse beetles.

Fungi or mold feeders

Another important group of insects that can be found in and around facilities that store and process grain are the fungal feeders. These are not a single taxonomic group, but contain a variety of species that feed on fungi associated with degrading grain. While they can be present in large numbers, they do not normally cause economic damage since they do not typically directly damage the food material but instead feed on the fungi growing on the grains. However, they can be indicators of a moisture issues with stored grain or a food facility. They are often found associated with moist grain and product spillage accumulations outside of food facilities, but since they have wide host ranges and are good fliers and colonizers, they can disperse in from other locations in the surrounding environment. Often finding these species inside may indicate that there are favorable conditions in the surrounding environment, but they will likely have difficulty establishing inside a well-maintained facility. Establishment and reproduction inside facilities and in grain storage typically indicates moisture management problems.

Included in this group are three species in the Mycetophagidae family that are commonly found at food facilities: the spotted hairy fungus beetle, *Mycetophagus quadriguttatus*; the hairy fungus beetle, *Typhaea stercorea*; and *Litargus balteatus,* which is also sometimes called a hairy fungus beetle. These beetles are small (0.08-0.12 in, 2-3 mm), oval shaped, and covered with fine hairs. The spotted hairy fungus beetle and the hairy fungus beetle *L. balteatus* have patterning on their elytra and club-shaped antennae. The clubs are made up of four segments in the spotted hairy fungus beetle and three segments, with the last one longer than the others, in the hairy fungus beetle *L. balteatus*. The hairy fungus beetle, *T. stercorea*, is more uniform brown in color; the hairs on the elytra form parallel lines, and the antennae have a club made up of three segments. Without careful examination these species have sometimes been confused with other stored-product pest species such as warehouse beetles or red flour beetles.

Silken fungus beetles are a group of species in the family Cryptophagidae that feed on fungal spores, mold, and wet plant and animal materials. They are very small (0.05-0.08 in, 1.3-2 mm), flattened, and hairy. They have projections along the side of pronotum, hair on the elytra, and clubbed antenna. These beetles can be found worldwide and typically are associated with moist grain or other spillage, and are commonly found exploiting outside spillage accumulations.

The foreign grain beetle, *Ahasverus advena* (Waltl), is a minor secondary pest of a wide range of foods, but it does not usually exploit dry and clean grain. It is in the same family as the sawtoothed grain beetle and merchant grain beetle and is similar in appearance, except that the sides of the pronotum, instead of having saw-like projections, have curved sides and projections just at the front and back ends of the pronotum. This beetle is a strong flier and often associated with outside spillage accumulations. It is typically found exploiting moldy grain and is sometimes found associated with damp, new wood construction.

Corn sap beetle, *Carpophilus dimidiatus,* in the family Nitidulidae, is also commonly found associated with moist and degrading grain. A number of species of Nitidulidae are occasionally found with stored products and are generalists often found associated with carrion, fruit, and damp plant material. These are oval and flattened beetles (0.08-0.16 inches, 2-4 mm) with elytra that are shorter than the abdomen, leaving end of the abdomen exposed when looking from above. Their color can vary from brown to black, and sometimes is marked with lighter colored spots. Antennae have a flattened and rounded club. Other species of *Carpophilus* are similar in appearance and can be difficult to separate from each other. Minor pests in stored grain or food facilities, but often associated with spillage outside of food facilities, can immigrate into structures. They are very active dispersers and quickly colonize and rapidly develop in temporary resource patches such as moist, spilled grain.

Psocids

Psocids, commonly known as book lice, are another group of insects that can be found in stored grains. High numbers can be indicative of quality issues with the grain, and there is evidence that psocids are becoming more abundant in food facilities. They are small (most stored-product pest species are about 0.04 inches, 1 mm, long) soft-bodied insects with long thread-like antennae and may or may not have wings. Psocids do not have complete development like the beetles and moths, so both the adults and the immatures look similar to each other. The most commonly found stored-product pest species are in the genus *Liposcelis* and lack wings. Identification of psocids to species can be difficult, typically requiring high magnification. An online key for the identification of stored-product psocids is also available.

Because of their small size, they are most likely to be confused with mites, but mites have four pairs of legs and psocids have three pairs of legs. Psocids also have distinction body sections and long antennae, which mites do not. Four species of psocids are most abundant in stored products: *Liposcelis bostrychophila*, *L. decolor*, *L. entomophila*, and *L. paeta*, and there are keys available as discussed above to identify them to species. Proper identification is important since the species can vary considerably in their susceptibility to different insecticides. The major psocid pest species in stored-products are wingless. However, winged psocids can be found frequently in and around food facilities, but they probably represent incidental invaders.

Mites

Mites are arachnids in the order Acari, and are not insects, because, unlike insects, they have four pairs of legs and two body parts. Mites are typically very small (about 0.5 mm) and have oval bodies with little or no differentiation of their two body regions. Over 50 species of mites have been found associated with stored products: some feed directly on stored products, but other mites are predators, feed on fungi, or are parasites of other stored product pests such as birds or rodents. Mites can be important pests of stored food worldwide, but their economic importance varies considerably with location, commodity, and management practices. Some mite species can cause allergic reactions in people. Mites are most likely to be a problem in temperate and humid climates, but some products such as cheese, pet-food, and oilseeds are infested under warmer and drier conditions. Mites infest a wide range of stored food products including grain, flour, cereals, dried fruits and vegetables, herbs, powdered milk, pet foods, cheese, tobacco, oilseeds, and livestock feed. During outbreaks, mite populations can build up to extremely high densities and become damaging.

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Chapter 2: Key Stored-Product Insect Pests

Section 6: Rodent and Bird Management

Introduction

Rodents and birds are notorious sources of damage and filth. Their presence is also hard to hide. Rodent and bird evidence are frequently the culprit of sensational food safety incidents. The rodent management component of pest management service contracts is frequently the most expensive part of the service, and it sets the tone for how a comprehensive pest management program is designed. Vertebrate and bird pest management is an especially dynamic field at this time because, in the face of critical needs, the public pushes for humane, non-lethal means of pest control. The public also has a great deal of sensitivity for protection of non-target animals, and they are not afraid to use public relation campaigns to order this protection, causing concern to food plant pest management professionals. At the same time, food production plants must manage these pests. This section of the manual is meant to provide an overview of rodent and bird management procedures and is in no way meant to be all inclusive or applicable to all locations.

Rodents

Rodents are a significant part of any food plant pest management program. Rodents, mice and rats in particular, reproduce and multiply to build their populations rapidly. Mice and rats can eat large amounts of raw material, while their excrement can contaminate enormous amounts of product and transmit disease. It is no surprise that stories about rodent contamination of food or in restaurants are often in the news.

A rodent management program will set the tone for the design of a comprehensive pest management program, as a rodent control program must be in place 24 hours a day, 7 days a week, and in all seasons of the year. While rodent activity outside may decline in areas of cold weather, rodents will continue activity inside the plant and they can still enter the facility with shipments of food, ingredients, or packaging materials. Pest managers must remain on constant alert with a preventative program versus a reactive one.

Assessment-based Programs

Industry standards on pest control have transitioned from being a purely formula-based setup to becoming an assessment-based scheme. Whereas previously the rules specified how far apart traps needed to be placed and how often they should be checked, now the program is more about continually inspecting the facility to see if there is evidence of rodent activity or the possibility that rodents could be attracted to the plant area.

The Wal-Mart sustainability program is the biggest evidence of companies that are moving toward this type of program. The Global Food Safety Initiative (GFSI) strives to provide consumers with the assurance that the food they are buying is safe. Therefore, The GFSI sets food safety requirements that must be met by a facility and any facilities that do business with that facility.

In 2008, Wal-Mart stores became the first nationwide U.S. grocery chain to require that suppliers of its private label and other food products such as produce, meat, fish, poultry, and ready-to-eat foods have their factories certified against GFSI standards. The GFSI requires that food suppliers achieve factory audit certification against one of its recognized standards. Audits are completed by third party auditors. Wal-Mart's initiative is significant because it has set a higher standard for all other grocery chains. Moreover, Wal-Mart's actions pressure other retailers to endorse the same standards.

Common Rodent Similarities and Differences

Mice and rats are normally nocturnal and secretive. Sightings of them during the day indicate a bad infestation. Obviously any sighting of these rodents in a milling facility indicates cause for alarm. Mice and rats can transmit disease to humans in many ways including: direct contact, contact with rodent feces, urine, or saliva, and through rodent bites. Worldwide, rats and mice can spread over 35 different diseases. Rodent hair and excrement can easily contaminate product. Moreover, these pests can carry mites, fleas, and ticks. Unfortunately, the biology of these pests allows them to reproduce quickly and often as shown in Table A.

Biological Traits	**House Mouse**	**Norway Rat**	**Roof Rat**
Sexual maturity attained	1 ½ months	2-3 months	2-3 months
Gestation period	10 days	23 days	23 days
Litter size	5-6	8-12	6-8
Litters per year	Up to 8	4-7	4-6

Table a: Biological traits of commensal rodents

Mice and rats are colorblind and their eyesight is bad in general, but it is compensated for by good hearing and an acute sense of smell. These traits allow them to hide during the day and to locate sources of food. Since they do not see well, their whiskers allow them to feel their way around walls and other surfaces such as equipment and pallets. Their whiskers also help them to feel so that they can avoid traps, etc. Mice and rats are able to gnaw through materials such as wood, cardboard, packaging, copper, cinderblock, and uncured concrete, causing spillage and other issues. They have also been known to chew through wiring, which can result in fires in the plant.

Some of the behaviors of mice and rats are shown in Table B:

Behaviors	House Mouse	Norway Rat	Roof Rat
Water required	No, if some retrieved from foods	Yes	Yes
Nocturnal	Yes	Yes	Yes
Climbers and swimmers	Yes	Yes	Yes
Cautious movers and accepters of food	No	Yes	Yes
Readily explore new objects and sample new foods	Yes	No	No
Like to be concealed, hidden	No	Yes	Yes
Move along in "runs" that they have deemed safe	No	Yes	Yes

Table B: Behaviors of commensal rodents

Rodent Management

Current tools and techniques for rodent management include sanitation, inspections, and use of trapping and baiting tools. While sanitation and inspection methods have been discussed earlier in this manual, the focus on this section will be the actual removal methods. Of course, sanitation and rodent management go hand in hand. You cannot have a good rodent management program if you have a poor sanitation program. Harborages and sources of food must be eliminated from the plant where they don't belong. Otherwise, rodents will be able to continue to multiply and live even when an area is being set with traps.

Before discussing rodent management further, it is important to understand that targeting these commensal rodents can also target semi-commensal rodents and other non-target animals including house pets. For this reason, all plant sanitarians must understand that the public opinion does not take kindly to the killing of animals, even if they may be pests.

The remainder of this section will discuss rodent trapping and baiting, how the baits work, trap monitoring, and methods to exclude rodents from the mill.

Trapping and Baiting

The two most highly successful methods of rodent control include trapping and baiting.

A rodent trap (*i.e.*, snap trap, glue board, multiple catch trap or rodent bait station) is considered a device that will attract and capture a rodent, most often killing it once trapped. The exception is rodent baits, which kill the rodent after ingestion of a small quantity of toxic bait. All these traps can provide immediate and tangible results. For example, snap traps and multiple catch traps provide visual evidence.

Bait stations are another option for both mice and rats. Bait stations are enclosed containers that hold enough bait to kill rodents as they feed. They are constructed so that a mouse can get into the station, but children, pets, and other small animals cannot. The U.S. Environmental Protection Agency dictates that rodent bait stations must be secured in place and of the tamper resistant variety. It is recommended that rodent bait only be used outside because it can kill many rodents at once; moreover, if the dead rodents cannot be found, dealing with the odor could be a problem. Additionally, rodent bait used inside can become a product contaminant through spillage or rodent translocation of bait.

Several types of bait are available including blocks, pellets, and liquid sources. Use of rodenticides, of course, require strict adherence to the label directions. Rodenticides are poison baits and should be used in areas where domestic animals and children can't reach.

How Baits Work

Most rodent baits work by causing internal bleeding of the rodent. These are known as anticoagulants. Some first-generation anticoagulants include: Warfarin, Pindone, Chlorophacinone, and Diphacinone. These rodenticides must be ingested by the rodent over a period of days. Normally, a 15-day supply of bait should be available in a bait station. Second generation anticoagulants include Brodifacoum and Bromadiolone and were created due to Warfarin resistance. In addition, these rodenticides are extremely potent and have the ability to kill rodents after one feeding. This technology continues to change, requiring pest management professionals to keep abreast of such changes and to adapt their programs accordingly.

Non-anticoagulants are also available and have less potential for secondary poisoning. They are no longer considered useful for rodent control. At the current time, only zinc phosphide, cholecalciferol, and bromethalin are registered and available for commensal rodent control. Depending on the non-anticoagulant, they may be left out for consumption over a period of days, but Bromethalin can also kill rodents after only one feeding.

Monitoring Traps

All bait traps should be monitored according to the instructions on the label. Some traps do not need to be refreshed for several days, whereas others require daily or every other day inspection. Modern bait stations have the bait suspended around a rod so that the bait is always fresh. For less modern traps, removing the bait that becomes unreachable or scattered is recommended. It is highly recommended that no loose bait ever be used in a bait station as it can be translocated by a rodent to an undesirable location and become a contaminant (*i.e.*, pallets, food/ingredients in the warehouse), or it could be translocated to a location where a non-target organism can be exposed, causing toxicity.

Exclusion

Exclusion involves creating physical barriers to keep the rodents out of the plant. Some of these methods include:

- Install an at least 18-inch gravel perimeter ("pea size" gravel is best as it is hard for rodents to dig and keep it in one place) around the exterior building perimeter
- Where storage outside is required, use racks that are at least 18 inches off the ground
- Keep all garbage containers tightly closed
- Establish rodent bait stations around the outside perimeter of the plant
- Do not allow scrap lumber, old metal, or debris to accumulate on the plant premises
- Use a vegetation inhibitor on railroad tracks and other areas where no foliage whatsoever is desired
- Do not permit weeds or high grasses on the property adjacent to the plant

Birds

Raw or spilled grain is an extremely desirable food for nuisance birds, so these animals can be found frequently feeding, roosting, or nesting near food plant facilities. Pigeons, sparrows, and starlings are very common, but their presence is undesirable because they carry diseases. Their droppings, in particular, can lead to product contamination and other problems. Dried pigeon droppings that are stirred up by the cleaning process or otherwise can spread contaminants into the air, affecting both product and personnel. Breathing in dried pigeon droppings can lead to human diseases, in particularly histoplasmosis, cyptococcosis, or psittacosis. Birds' nests are another problem as these are a source of other pests including spider beetles and larval dermestid beetles.

Nuisance Bird Management

In the United States, three birds are considered nuisance birds meaning that they are not under federal protection: the English Sparrow, the Feral Pigeon, and the European Starling. Since all other species of birds are protected, bird management can be a big problem as a plant facility does not want to target a non-nuisance bird. All plant sanitarians should know and comply with all federal, state, and local laws that apply to bird control.

Sparrows in particular have an easy time accessing plant facilities and are considered the most highly troublesome among pest bird species. Their size allows them to gain access to food processing facilities, and their nesting habits in the flour load-out areas increase the possibility of contaminated product. In addition to sparrows, pigeons, and starlings, other species that cause problems in plants are geese, swallows, and gulls.

Birds can be incredible pests around a plant, and by their biology alone, they are extremely difficult to control once their presence has become established. These pests are attracted to the large amount of grain spilled around the facility as well as the architectural details of the plant such as gutters, ledges, and any structures that have space behind them where a nest can be built. Plants that have more areas for birds to roost and gather will attract greater numbers of birds than plants having very few or none of these types of areas.

	No. of Eggs	Fertilization Period	Age to maturity	Number of chicks produced per year
Pigeons	1-2	17-22	4 weeks	10-12
Sparrows	5-6	10-17	4 weeks	35
Starlings	3-6	11-14	4 weeks	10

Table C: Biological traits of pest birds

Most plants give very little effort to bird management unless there is a need for remediation. If the public notices sick or dying or dead birds in public areas, they are very unhappy with the culprit, no matter who it is. The pressure that these constituents can place on the plant is tremendous, and the national organizations that cater to animal friendliness can cause an uproar with any company that does not oblige them.
Bird management at food plants can be best handled by sanitation, inspection, exclusion and control.

Sanitation
Since birds are attracted to spilled grain, it is obviously best to have a sanitation plan that includes sweeping up spilled grain several times a day. This includes inside the plant as well as outside the plant, particularly in the loading area, tracks, along docks, and dock canopies.

Inspection
Preventative measures to keep birds from entering a plant are always a good idea. Some places to inspect in particular and actions to take include:

- Close all openings in walls, eaves, or in the roof that are not necessary for the operation of the plant
- Fit any doors that need to stay open with plastic strips to prevent bird entry
- Repair all broken window panes immediately
- Screen all windows that must be left open
- Keep doors closed or screened when they are not in use

Control
When a bird population must be controlled, a plant has several options including: harassment, scare devices, exclusion, baiting, and lethal methods.

There are a number of harassment and scare devices on the market today. These include visual repellents such as owls, hawks or flashing lights, bird netting, and stainless-steel spikes. Other repellants include loud or ultra-sonic noise-making devices. However, visual and sound scare tactics are things that birds can easily adapt to over a number of days. They usually do not work well for plants as the birds quickly figure out that no “harm” comes to them.

Exclusion is a method to keep birds out of the plant where they may enter to roost or rest. Exclusion is the use of bird netting or simply building structures around the current ones that will keep the birds out. This includes adding tight screens on windows or over any holes in the exterior walls. Birds are also attracted to the loading area, although enclosed, on top of the ceiling trusses. In this case, screens can be installed underneath the trusses to prevent the birds from reaching them.

Trapping birds is another solution, but it is not very effective for plants as the relocation takes more time and other birds will come back anyway. Pigeons are notorious for this.

Lethal means of killing pest birds can be used when all other methods fail and when federal, state, and local regulations permit such action. Before using these chemicals, known as Avicides, all local, state and federal regulations must be followed. One use of Avicides involves applying the pesticide to places where the pest birds perch. The chemical is absorbed through the feet and makes its way into the digestive system, often causing death. Again, public opinion comes into play here as the birds may not die on the plant property but where their presence is highly distasteful to many. Another factor is that non-nuisance birds may also be attracted to the poison.

Baiting of birds is considered the deliberate placing of common. non-lethal food so that birds will learn when and where to feed. Once this pattern is established, an "Avicide" (toxic to birds) is included with the food. While these methods are explained quickly here, they are not meant to be taken lightly. Public opinion of birds, no matter what type, tends to favor the birds. If lethal means of controlling them must be used, the feeding and other patterns of the birds should be studied thoroughly.

Summary

In summary, rodents, particularly mice and rats, and birds can be a tremendous problem for a mill. Many plants have discovered that the secret to keeping these pests out of the mill is to establish a routine in which the mill and surrounding areas are inspected daily to look for signs of pest activity. Several options are available once a problem is detected. For rodents, traps and baits are used, but the label instructions must be followed. Birds may also be baited which also requires following the label on the product. Other methods of rodent and bird exclusion are available.

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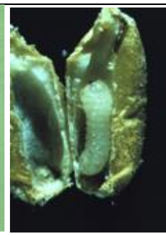
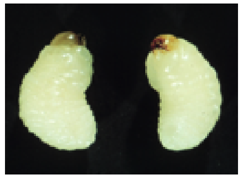
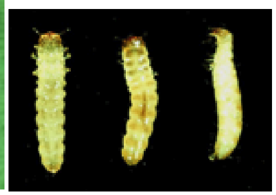
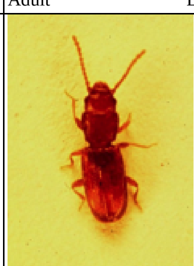
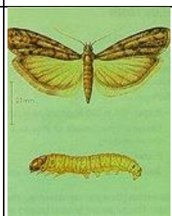
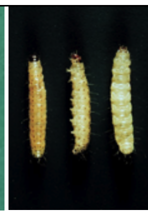
Table 1. Information Matrix for Common Stored Product Insect Pests[1]

Common name	Latin name	Pictures	Adult - Identification	Distribution	Where commonly found	Damage	Conditions supporting population growth	Development time under optimal conditions	Typical adult lifespan & number of eggs laid	Flight	Pheromone lures commercially available
Beetles (Coleoptera)											
Lesser grain borer	*Rhyzopertha dominica* (Bostrichidae)	 Adult  Adult and larva  Larva inside kernel	Cylindrical shape, many small pits on elytra, head points downward and not visible from above (covered by pronotum), antennae loose club shaped 0.08-0.11 in (2-3 mm) long	Worldwide	Stored cereal grains such as wheat, corn, rough and brown rice, outside and in wooded areas	Primary feeder on grain, larvae develop inside kernels, adults feed and cause rough edged holes in grain, produce IDK, characteristic pungent odor	68-100°F (20-38°C) >30% rh	25 days at 93°F (34°C), 70% rh	3 months (400 eggs)	Yes	Yes – aggregation pheromone attracts both species
Rice weevil	*Sitophilus oryzae* (Curculionidae)	 Adult  Adult and larva	Elongated snout, elbowed antennae, dark brown in color with orange or yellow spots on elytra, round punctures on thorax, have membranous wings under elytra 0.11-0.18 in (3-4.6 mm) long but size varies considerably	Worldwide, but more prevalent in tropical and temperate regions	Stored cereal grains such as wheat, corn, rough and brown rice, often found in spillage outside bins, pasta and pet food	Primary feeder on grain, larvae develop inside kernels, adults chew small round holes in kernels, females lay eggs in these hole and fill with a plug	59-93°F (15-34°C) >40% rh	25 days at 86°F (30°C), 70% rh	6 months (150 eggs)	Yes	No
Maize weevil	*Sitophilus zeamais* (Curculionidae)	 Adult	Same as rice weevil, can not reliably separate these two species with dissection of reproductive organs	Worldwide, but more prevalent in tropical regions	Similar to rice weevil	Same as rice weevil	59-93°F (15-34°C) >40% rh	25 days at 86°F (30°C), 70% rh	6 months (150 eggs)	Yes	No

Granary weevil	*Sitophilus granarius* (Curculionidae)	 Adult  Larvae	Similar to rice and maize weevils, but shiny reddish brown without orange or yellow spots on elytra, oval punctures on thorax, lacks flight wings under elytra 0.11-0.18 in (3-4.6 mm) long but size varies considerably	Worldwide, but more prevalent in temperate regions	Similar to rice weevil	Same as rice weevil	52-93°F (11-34°C) >40% rh	25 days at 86°F (30°C), 70% rh	6 months (200 eggs)	No	No
Sawtoothed grain beetle	*Oryzaephilus surinamensis* (Silvanidae)	 Adult  Larvae	Small, flattened, parallel sides, thorax has six sawtooth-like projections on sides and three ridges on top, length of head behind the eye is about the diameter of the eye (longer than the merchant grain beetle) 0.1-0.15 in (2.5-3.5 mm) long	Worldwide	Most commonly found on grains and milled and processed grain products, but also exploits dried fruits, nuts, and other commodities	Secondary pest of cereal grains, major pest of processed grains in mills, processing facilities, and warehouses; very effective at finding flaws and infesting packaged foods	68-100°F (20-38°C) >10% rh	20 days at 86-90.5°F (30-32.5°C), 70% rh	6-10 months (280 eggs)	No	No
Merchant grain beetle	*Oryzaephilus mercator* (Silvanidae)	 Adult  Larva	Same as sawtoothed grain beetle, except the length of head behind the eye is much shorter than the diameter of the eye (shorter than the sawtoothed grain beetle) 0.1-0.15 in (2.5-3.5 mm) long	Worldwide	Cereal grains and milled and processed grain products, but more often exploiting dried fruits and oilseeds	Similar to sawtoothed grain beetles, but generally less significant a pest	64-100°F (18-38°C) >10% rh	25 days at 86-90.5°F (30-32.5°C), 70% rh	6-8 months (200 eggs)	Yes, but rarely	No
Rusty grain beetle	*Cryptolestes ferrugineous* (Laemophloeidae, formerly Cucujidae)		Small, flattened, parallel-sided, reddish in color, very long beaded antennae (about half of total body length), head and thorax are large and together encompass half the body length 0.1 in (2.5 mm) long	Worldwide, cold tolerance makes it more predominate in colder climates,	Cereal grains and products, seeds and dried processed foods, major pest of wheat in colder climates	Typically a secondary pest, but can tunnel if enter through small cracks in grain caused by harvesting and handling, important pest in cold climates, both adults and larvae feed and are cannibalistic	68-108.5°F (20-42.5°C) 40-90% rh	21 days at 95°F (35°C), 90% rh	3-8 months (240 eggs)	Yes	No

		Adult									
Flat grain beetle	*Cryptolestes pusillus* (Laemophloeidae, formerly Cucujidae)	 Adult	Same as rusty grain beetle	Worldwide, predominate species in tropical climates	Cereal grains and products, seeds and dried processed foods	Typically a secondary pest in grain, but can tunnel if enter through small cracks in grain, in tropical climates can exploit a wider range of products, adults and larvae feed and are cannibalistic	63.5-99.5°F (17.5-37.5°C) >50% rh	22 days at 95°F (35°C), 90% rh	Up to 9 months (200-500 eggs)	Yes	No
Red flour beetle	*Tribolium castaneum* (Tenebrionidae)	 Adult  Adult (antennae)  Larvae	Reddish-brown, shiny, small indentations on pronotom, similar to confused flour beetle, but last three segments of antenna form a club and the gap between the eyes, from underside of the head, is narrow 0.12-0.2 in (3-5 mm) long	Worldwide, tends to be more prevalent than confused flour beetle	Grain and grain based products, oilseeds, nuts, dried fruits, spices, beans, predators and scavengers	Secondary pest in grain, but major pest of milled and processed grain, the major pest species in mills, larvae and adults feed but damage is primarily due to contamination of product	72-104°F (22-40°C) > 1% rh	20 days at 95-99.5°F (35-37.5°C), 70% rh	Several months to several years (360 eggs, most in first 100 days)	Yes	Yes – aggregation pheromone that attracts both sexes, same lures work for confused flour beetle as well
Confused flour beetle	*Tribolium confusum* (Tenebrionidae)	 Adult  Adult (antennae)  Larvae	Similar to red flour beetle, but the last three segments of antennae gradually widening and there is a wide gap between the eyes when looking from underside 0.12-0.2 in (3-5 mm) long	Worldwide	Grain and grain based products, oilseeds, nuts, dried fruits, spices, beans, predators and scavengers	Secondary pest in grain, but major pest of milled and processed grain, the major pest species in mills, larvae and adults feed but damage is primarily due to contamination of product	66-99.5°F (19-37.5°C) > 1% rh	25 days 90.5°F (32.5°C), 70% rh	Several months to several years (360 eggs, most in first 100 days)	No	Yes – aggregation pheromone that attracts both sexes, same lures work for red flour beetle as well
Cigarette beetle	*Lasioderma serricorne* (Anobiidae)	 Adult  Adult (side view)  Larvae	Oval shaped, head is pointed downward and difficult to see from above, long sawtooth like antennae with similar width over the whole length, elytra smooth and covered with fine hairs	Worldwide, common in tropical climates. Overwinters in heated structures in temperate regions	Very wide range of foods of plant and animal origin, including spices and processed foods, major pest of tobacco, common in food processing facilities, warehouses, can penetrate packaged foods	Larvae cause most feeding damage, adults don't feed or feed only a little, larvae and adults can chew holes in packaging and tunnel in food (form small circular holes)	68-100°F (20-38°C) >25% rh	26 days 86°F (30°C), 70% rh	< 1 month (100 eggs)	Yes	Yes – sex pheromone attracts males

			0.08-0.16 in (2-4 mm) long								
Drugstore beetle	*Stegobium paniceum* (Anobiidae)	 Adult  Adult (side view)  Larva	Similar to cigarette beetle, but tip of antennae is widened to form a club and elytra have lines made from rows of pits 0.08-0.20 in (2-5 mm) long	Worldwide, but more common in temperate than tropical climates	Very wide range of foods of plant and animal origin, including spices and processed foods, herbal medicines and pharmaceuticals, can penetrate packaged foods	Larvae cause most feeding damage, adults don't feed or feed only a little, larvae and adults can chew holes in packaging and tunnel in food (form small circular holes)	59-93°F (15-34°C) >35% rh	40 days 86°F (30°C), 60-90% rh	25 days (100 eggs)	Yes	Yes – sex pheromone that attracts males
Warehouse beetle	*Trogoderma variable*	 Adult  Adult and larva  Larva	Oval shape, black with lighter variable patterning on elytra, covered in fine hairs 0.11- 0.14 in (2.7-3.5 mm) long, females generally larger than males	Worldwide, but more common in temperate climates	Dried animal and plant material, cereals and cereal products, animal fur and feathers, dead insects, pet food	Larvae cause feeding damage, adults don't feed, larvae and adults can chew holes in packaging and tunnel in food (form small circular holes), leave cast cuticles and hairs that are a health hazard	63-99°F (17-37°C)	30 days 86°F (30°C)	9-50 days (150 eggs in first 3 days then declines rapidly)	Yes	Yes – sex pheromone that attracts males
Hairy fungus beetle	*Typhaea stercorea* (Mycetophagidae)	 Adult  Larva	Small, flattened, light brown, oval shaped, somewhat hairy with hairs on elytra forming parallel lines, clubbed antennae 0.09-0.12 (2.4-3 mm) long	Worldwide	Mold feeder, but can also feed on a wide range of plant material including grain and grain products, often associated with damp products	Associated with degrading grain, spillage, and grain prior to harvest, wet hay, and other sources outside of stored grain, presence in grain indicates poor management, can carry *Salmonella*	63.5-86°F (17.5-30°C) >70% rh	15 days 86°F (30°C), 80-90% rh	Long lived (up to 128 eggs in a day on fungi)	Yes	No
Moths (Lepidoptera)											
Angoumois grain moth	*Sitotroga cerealella* (Gelechiidae)	 Adult  Adult  Larva	Forewings grey brown with a small black spot, wings fringed with long fine hairs, forewing tapered and hindwing has fingertip like projection, small 0.51-0.75 in (13-19 mm) wingspan	Worldwide, but more common in warm temperate and tropical climates	Whole grains especially rice and corn	Primary feeder on whole grain, can infest grain in field, especially in tropical climates, larvae feed inside grain, leave large exit hole with pupal case often sticking out	61-95°F (16-35°C) >30% rh	30 days at 86°F (30°C), 75% rh	< 1 week (40-150 eggs)	Yes	Yes – sex pheromone that attracts males

Indianmeal moth	*Plodia interpunctella* (Pyralidae)	 Adult  Adult and larva  Larvae	Forewings have two colors, with upper part of wing tan and lower part copper colored 0.55-0.87 in (14-22 mm) wingspan	Worldwide, especially prevalent in warm-temperate and tropical climates	Wide range of grains, grain based products, beans, dried fruits, nuts, chocolate, and other processed products	Secondary pest in grain, larvae feed and adults do not feed, larvae produce silk that binds food and waste material together, larvae can enter and adults lay eggs in packaging flaws	59-95°F (15-35°C) 25-90% rh	30 days at 86°F (30°C), 75% rh	< 1 week (150-200 eggs)	Yes	Yes – sex pheromone that attracts males Same lures used for almond moth and Mediterranea n flour moth
Mediterranean flour moth	*Ephestia kuehniella* (Pyralidae)	 Adult/Larva  Adult  Larva	Forewings are gray with black markings of wavy lines or dots, hindwings are cream to light gray with hairs along margin, tips of wings are rounded, most similar to almond moth in appearance 0.63-0.98 in (16-25 mm) wingspan	Worldwide, especially prevalent in temperate climates, more common in Europe than North America	Grain based products, especially flour, cereals, nuts, dried fruits and vegetables, oilseeds and products; found in wide range of facilities stored grain bins, mills, warehouses, bakeries, etc	Secondary pest in grain, larvae feed and adults do not feed, larvae produce silk that binds food and waste material together	54-86°F (12-30°C) >0% rh	40 days at 77°F (25°C), 75% rh	7-21 days (150-200 eggs)	Yes	Yes – sex pheromone that attracts males, same lures used for Indianmeal moth and almond moth
Almond moth	*Cadra cautella* (Pyralidae)	 Adult  Larvae	Forewings are light gray to brown with straight dark lines or banding near outer portion of wing, hindwing is light gray to beige with fringe of hairs on margin, wing tips are rounded 0.51-0.83 in (13-21 mm) wingspan	Worldwide, but more prevalent in warm and humid temperate and tropical climates	Wide range of products, including grain, grain based products, oilseeds, nuts, dried fruit; found associated with mills, bulk stored grain, warehouses, railroad cars	Secondary pest in grain, larvae feed and adults do not feed, larvae produce silk that binds food and waste material together, important pest of nuts and dried fruit	63-99°F (17-37°C) >20% rh	26 days at 86°F (30°C), 75% rh	14 days (up to 500 eggs)	Yes	Yes – sex pheromone that attracts males, same lures used for Indianmeal moth and Mediterranea n flour moth

[1]Pictures from USDA ARS and J. F. Campbell, information compiled primarily from Rees (2004), Hagstrum et al. (2012), and Hagstrum et al. (2013); information on where commonly insect species are commonly found is only a partial ist; information on adult lifespan and number of eggs laid are only rough guides since these values are strongly influenced by the environment and the methods used to collect the data.

Chapter 3

IPM Components

Section 1: Inspection and Monitoring
- a. Mill Inspection Guidelines
- b. Monitoring – Trending Tools and Interpretations
- c. Managing the Pest Management Company

Section 2: Flour Mill Sanitation
Section 3: Physical Controls – Sifters and Impact Machines
Section 4: Chemical Controls
Section 5: Using High Temperatures (Heat Treatments) for Stored Product Pest Management

Chapter 3: IPM Components

Section 1: Inspection and Monitoring

Introduction

Detailed floor level inspections coupled with a comprehensive monitoring program are key components for an effective Integrated Pest Management (IPM) program. The goal is to collect significant pest related data that can be reviewed and analyzed to make educated decisions to manage and prevent existing and/or future pest pressure. This information will also be beneficial in determining if sanitation, maintenance, housekeeping and other prerequisite programs are functioning properly. Periodic and annual reviews of this data may determine that adjustments or modifications need to be made to the IPM program.

In today's food industry it is common practice to utilize a contracted service to provide IPM activities at a food facility, while some food facilities have added job responsibilities or created departments for in-house personnel to handle the IPM activities. Whether using a Pest Management Company (PMC) or in-house personnel, food facility management still has a responsibility to be engaged and contribute to the overall IPM program. The food facility must set the expectations for the pest management professional (PMP) or in-house program and work in conjunction with them to ensure food safety, occupational safety, site security, and other company standards are upheld.

Food Safety Committee

To be most effective an IPM program should have a multi-disciplinary food safety committee. This committee should have representation from each department to ensure a balanced approach and stress the importance of food safety for each department. It may also be beneficial to include at least one or two hourly staff members on the committee. Often times these individuals are already aware of some of the challenging areas within the facility, but the most important function may be that of a messenger. This role is able to convey the importance of the food safety committee and culture to their co-workers. Employees also respect having a seat at a table and are able to share their thoughts and ideas as well.

Pest prevention should be the main focus of IPM and it takes a well-rounded dedicated food safety committee to partner with PMPs and in-house personnel. Establishing expectations and goals for the IPM program will demonstrate that level of commitment. They will also help ensure that PMPs and/ or in-house personnel do not become "trap checkers". Some examples may be:

- Thresholds and escalation guidelines
- Documentation and communication methods
- Periodic/annual analysis and program reviews

Self-Inspections

Inspections of the mill are an essential tool to assist in maintaining and monitoring the food safety level and supporting the IPM program. The inspections can assist a facility in recognizing areas of concern, focusing effort and resources properly based on the results of the inspections, and sending a message to all employees that management cares about what is happening in the operation. These inspections are not a complicated tool, but they do require focus, effort, and follow-up. Budgeting must also be done to "fix" critical items found during self-inspections. A well-developed inspection program is a means to foster the culture of food safety.

The committee should understand the purpose of these inspections: to identify conducive conditions that can lead to pest related issues. The inspection is an assessment of a "moment in time" which identifies positive or negative conditions. In order to assess the operation properly, the team should be prepared to conduct an extensive physical inspection of the facility and equipment. This may require climbing, crawling, opening equipment, interviewing employees, observing operational practices, etc. Members of the inspection team should be properly dressed in work clothing that will allow them to get dirty.

One important point of the inspection is to assure these activities are done safely to not jeopardize the safety of the product or the individuals conducting the inspection. The team should be familiar with the plant's safety rules to prevent injury. Only trained persons knowledgeable of the equipment should attempt to open equipment for detailed inspection. The inspector should also not be the source of contamination. An example would be to only use clean and designated tools for scraping materials on a product contact surface. A tool that has been used for scraping out a floor joint should not later be used to scrape product on equipment.

The inspection team must understand what it is they are evaluating. Having knowledge of the standards to be used is critical. These items may include knowledge of the Stored-Product Pests & others common at the location (refer to chapter 2), Good Manufacturing Practices, customer requirements, third party audit standards, company guidelines, etc. A simple analogy would be that of a person knowing the rules and laws of operating a motor vehicle prior to driving.

Keen Observer

A keen observer is trained to think, analyze, associate, and look beyond what appears obvious. The food safety committee, or whomever will perform self-inspections, must learn to be keen observers to identify what needs to be done to make the place good for people and not for pests. This is thinking like the pest. For each kind of pest you want to manage, ask: How would the pest get in this area? What about this place is attracting it? The I.C.E. methodology is a simple concept to guide the inspection team to help develop keen observers.

> I = Identify: Is there a situation or condition that can be identified that can introduce or intensify a situation? The team should be able to recognize an issue and agree as to the importance.
>
> C = Control: Establishing appropriate and timely controls within the process environment to protect product and contact surfaces is imperative. These are often viewed as short-term or immediate corrective action.
>
> E = Eliminate: Develop and implement reasonable and practical solutions which effectively address underlying cause/reasons. This is the long-term corrective action to prevent reoccurrence.

The team should be equipped with proper tools to conduct thorough inspections. These tools should include items such as:

- Flashlight (brightness counts), 15-20,000 Lumens
- Inspection mirror (non-glass or polished metal)
- Scraper/ spatula
- Thermometer

- Hand tools, as allowed
- Documentation tools
- Writing tablet
- Writing implement/ pen
- Facility diagrams
- Hand-held computer
- Camera
- Recording device
- Hand lens or means to collect insects/ evidence
- An open mind

The team members should also have the ability to go from an inspection to an investigation. An example of this may be inspecting conveying equipment and finding insect activity inside. The team should then investigate the finding, inspect immediate area around the initial finding for additional activity and/or the origination source. The activity or observation should be documented on a facility diagram to help identify spatial trends or larger issues that are unable to be seen one dimensionally. Records like the Master Cleaning Schedule, IPM service records, Observation logs, etc. may be reviewed after the inspection to help determine a root cause and help with creating sustainable corrective actions.

Summary

The purpose of inspections is to not simply create a laundry list of items to be corrected, but to delve into the root cause of the concern and make necessary changes to prevent repeat occurrence. This chapter will provide a basic overview of how to conduct plant inspections, the importance of monitoring and data analysis and creating a partnership with whomever is performing the IPM activities.

Chapter 3: IPM Components

Section 3.1a: Mill Inspection Guidelines

General Inspection Guidelines
There are some simple guidelines to increase the effectiveness of these inspections. The first and most important item is to be able to recognize what is normal and what is not normal. The expectation in a milling environment is not to be dust free, but one must be able to evaluate what area of the facility is being inspected and know what is considered excessive. Is the dust at a level where there may be a safety concern for explosion? Are there signs of insect activity that indicate the material has been present for a period of time? Is the material crusted, which may also indicate longer presence?
To get the most out of an inspection the inspectors must be curious and willing to take the extra time and effort to evaluate these areas. **The goal of any facility should be to know it inside and out to the point that no third party inspector/ auditor should walk in from the outside and find surprise issues or areas that have been neglected.**

Goals of Inspection
The goal of the self-inspection is not to keep generating a "to do list" of items observed, as this will lead to lists that normally never get items fully completed with corrective action and follow-up. It can also lead to frustration as lists grow. Critical items must be noted and corrected as soon as possible. The repeated documentation of similar issues indicates a breakdown in employee training that must be addressed to eliminate such observations in the future. While focusing on the "critical" items is important, brushing aside "minor" items as unimportant can often lead to issues in the future. These, too, must be addressed with additional employee training.

This chapter will provide a basic overview of how to conduct a thorough inspection of the mill. Key items that should be inspected will be covered in detail in chapter 4. Keep in mind, all equipment discussed should only be opened when it is deemed safe by the operator and proper safety precautions, such as lock-out and tag-out have been followed.

The inspection should be conducted in two stages: 1. Physical inspection and 2. Review of records/ processes (as needed). An inspection can get out of control very quickly especially if trying to complete all aspects of it while in the plant. Time can get away from you and the rest of the audit can become rushed and not given the time needed to do a proper inspection. The inspection part should be designed for what it is, that moment in time you are observing conditions and practices in an area. Taking good notes and pictures from observations made will be important when reviewing records and processes. An employee or supervisor that hasn't arrived for their shift yet may need to be questioned and reasonable delay in creating a corrective action to get all the right information may help identify the true root cause. Keep in mind though, if a condition was observed that could impact the integrity of the product then it absolutely should be handled at the moment it was observed.

Stage 1: The Inspection
Knowing where to begin and how to evaluate the entire operation can be viewed as a daunting task. The inspection team may have limited time to inspect the operation. Typically, these

inspections should cover the entire operation on at least a monthly frequency. It may be beneficial to divide the facility into different areas so smaller sections can be covered each week. Mills generally have 6 distinct areas to focus on and the inspection normally follows the functions in order.

1. Exterior grounds
2. Receiving and storing the grain
3. Cleaning and tempering the grain
4. Milling
5. Product storage and blending
6. Packaging and shipping

Before the team enters the respective areas, a few guidelines should be established. How long will the inspection be conducted? This will help guide the team to ensure their entire area is covered. Many companies also split their teams into smaller groups to cover these areas. It is often difficult to get all members to be available to inspect as one large group. If the team is divided into smaller groups, it is recommended these teams be rotated in the respective areas and to also rotate team members so they are working with different individuals. This can be very advantageous for cross-training the members. It is also recommended that your IPM Technician participate in these inspections periodically or on each occurrence. They can provide additional guidance and point out issues/ concerns or areas that are frequently overlooked.
Often times, it will be the more significant findings that require further corrective action and follow-up. Pictures should be taken whenever possible to capture the observation, these will be helpful when reviewing the overall inspection with a larger group, or used as a reference when evaluating and developing a corrective action. During the inspection minor items may be discovered as well. An example may be finding tools or parts that are unaccounted for or debris lying on the floor. It may not be effective to document and leave all of these "minor" items in the facility. However, if they are simply picked up and addressed by the inspection team, there may not be a long-term corrective action. Some teams carry a small bucket with them during the inspection and gather up these "minor" or unaccounted for items. The contents of this bucket are then displayed on a table in an area where all employees in that department are able to view the materials and understand what has been identified within their areas. This can be beneficial to reinforce the food safety culture and commitment expectations.

Stage 2: Review of Records and Processes
Now that the physical part is completed, you may need to take a moment and collect your thoughts. This is where you will reflect on the inspection you just completed, notes made, pictures taken and start to think about what records or processes you may want to review. There shouldn't be a checklist outlining what records should be review each and every time. Each observation noted may require different records to review to determine the root cause. Identifying the root cause will be key to implementing the right corrective action so the initial issue does not become a repeat observation.

For example; an observation was made of mouse droppings in the basement of the elevator, the area was investigated further and notes/ additional observations made on area diagram in the physical inspection part. Next, when determining the root cause and developing corrective actions, certain records may need to be reviewed. These may include Master Cleaning Schedules to determine if the area is being cleaned as defined by the frequency (which may indicate if the droppings are new or old), IPM records to determine if there have been instances of recent captures (or if recommendations have been made to repair any deficiencies that haven't been completed yet), and previous inspection reports to see if this is a repeat issue.

An example is that during the inspection a keen observer found mouse droppings in the corner of the warehouse near the trash compactor. Possible records and processes to review:

- Pest control reports from last service
    - Pest control captures in that area (spatial map ideal)
    - Pest control records on bait stations or multi-catch traps on exterior of the area
    - Pest control recommendations/ observations in that general area (interior and exterior)
    - Also may look at the past month or quarter depending on what was found in the above reports
    - Pest observation logs if used
- Master Cleaning Schedules
- Talk to supervisor/ employee responsible for trash compactor & schedule
- Any notes made from inspection of exterior grounds in that area
- Ask if any recent changes have occurred in the area
    - Construction changes
    - Contractors onsite using that area for access
    - Removed equipment being stored near building on the exterior
    - Equipment stored outside brought inside
    - Other

These are some examples; it is really up to the food safety team on what records or processes they feel are pertinent and that will help to identify the root cause and prevent reoccurrence. Once corrective actions are determined, whether short term or long term, they should be organized by priority or significance and owners and target completion dates should be established. The entire food safety team should reconvene on a periodic basis to review the progress, identify any stumbling blocks, and update any needed changes accordingly.

Summary

As you can see, a milling environment requires a trained individual to conduct a thorough inspection. The inspection of the plant usually follows the functions of the process. The most effective inspectors are those who are keen observers, who are curious, ask questions, and are willing to get dirty during the inspection. Follow the evidence during the inspection and review records and processes to identify the root cause to help prevent reoccurrence. And, finally, always use caution during the inspection and ask facility personnel about safety or food safety requirements before opening any piece of equipment or machinery.

Chapter 3: IPM Components

Section 1b: Monitoring – Trending Tools and Interpretations

Introduction

Monitoring is the foundation for a successful Integrated Pest Management (IPM) Program. The goal of a monitoring program is to collect significant pest related data to help make good decisions when practicing various IPM techniques and strategies. In order to make sure good data is being collected, a proper program design must be established. A facility pest risk assessment must be performed by an expert in Pest Management. The risk assessment will help to determine where the facility is vulnerable to pest ingress or of existing issues going on. These observations made by the expert will provide guidance on developing a program design to mitigate and eliminate the pressures or existing activity.

Recommendations for the plant to make building modifications or change cultural practices may be needed. Certain recommendations may require capital expenditures, long term projects or just are not feasible to do so. The expert needs to incorporate the correct program design elements to mitigate any pressure or activity until corrections are made.

An example of this is site lighting. If a facility has poor site lighting, lights positioned directly above doors or other entryways, it can be assumed that insect pressure attracted to the facility will have a higher probability to gain access. The expert may recommend a better solution of having lights staged out away from the building shining towards it. In most cases this will be viewed as not being feasible and so the expert may recommend, as an alternative, the installation of lights that are not as attractive to insects. In addition to this recommendation, they may install insect light devices on the inside of the facility to monitor any pressure breaching the facility. This data will be beneficial for identifying exclusion opportunities, cultural practices or other conditions that exist outside the facility and help to determine the most effective sanitation or treatment strategies.

Once the facility pest risk assessment has been completed, program design developed and program implemented, the collection of significant data and interpreting the data is next.

Monitoring –Tools

Monitoring programs can provide a wide range of information, including the number and type of pests present, if pest populations are increasing or decreasing over time, location of concentration of an infestation and routes where pests may be entering a facility. The type of monitoring program used needs to be aligned with the goals of the pest management program. There is a wide range of monitoring tools and tactics available for monitoring pest activity. Multi-catch devices used for rodents, insect light devices and bait devices can be placed at strategic locations determined by the facility pest risk assessment. Pheromone monitoring devices for Stored Product Insects are typically intended to be more randomly placed in a grid pattern. Exterior placement is not routinely common, but it could provide valuable data of stored product insect pressure outside the facility. Including pheromone monitoring devices on the exterior of the facility should be considered for this reason. Pheromone monitoring and techniques will be the main focal point throughout this section, but the content of this section can be applied with any style of monitoring device used.

A range of insect monitoring devices, lures and attractants are commercially available for a wide range of stored product insects (e.g., sex pheromone, aggregate pheromone, kairomones, sticky boards and light traps). A monitoring device is an early warning indicator of a population within the vicinity of the placement. They provide continuous coverage in a facility which can provide quicker feedback on insect populations and concentration to an area or indicate a more wide spread issue than an in-depth visual inspection can. With the appropriate lure or attractant, they can draw insects from a wide area.

Pheromones are chemicals that insects release into the air to communicate with each other. A sex pheromone used in a monitoring program mimics the female insect releasing her pheromone to attract the male, whereas, an aggregate pheromone can attract both males and females. Kairomones can also be used as a stand-alone attractant or incorporated with a sex or aggregate pheromone lure to enhance the monitoring device and increase captures. Selection of a lure and a trap type is typically based on the target insect species or species that are susceptible to products stored or produced at the facility. Manufacturers and distributers have specific information on which devices work best for species encountered or have potential impact at your facility.

Other monitoring techniques may include tailings inspection or product sampling programs. This involves looking for insects within product samples or spillage accumulations within equipment or building structure. For example, tailings is a leading indicator to the condition of the internal process or equipment components. Having a comprehensive tailings inspection program can be beneficial to identifying suspect bins, equipment or some other change in the process that a further detailed inspection, cleaning or a chemical application needs to take place. Product sampling can provide similar benefits.

In food facilities, most of the insect population is hidden away in hard to reach areas and monitoring devices primarily capture adults that leave these hidden resources when disturbed or are in search of new resources. For example, a large set of data from a variety of laboratory experiments evaluating red flour beetle populations indicated that overall the percentage of adults was less than 15% of the total population.

Monitoring programs can provide very valuable information if used and interpreted correctly. A frequency to inspect the monitoring devices in the facility needs to be determined. This frequency should be determined by risk, but in most food facilities monitoring devices are inspected on a weekly frequency.

Action Thresholds and Escalation

Thresholds are a tricky topic; everyone wants to set a number at which point certain escalations, procedures, chemical applications are to be set into motion, but it is not that simple. Having a set number could take focus away from preventing increased pest activity that can damage or contaminate product. Likewise, not having a set threshold can do the same.

A threshold should be a realistic number established by species and risk to facility and/ or products produced or stored. It should be used as a guideline for the technician. In a prevention based program the technician should further investigate the area where an observation or capture was made regardless of how many. It may only take 30 seconds to scan the surrounding area, but by doing so and following any additional evidence, the technician may identify trouble areas that need attention. If the technician was to only record the finding and provide no additional action because the threshold was not reached, they may find on the next inspection elevated numbers well above the threshold, potentially requiring higher risk and reactionary tactics.

Historical records, if available and accurate, can be used to help look at trends annually and seasonally. This would be a good resource to use when creating thresholds. The threshold should be a number that is intended to drive the program to locating and appropriately addressing an area. They should not be set so high or so low that there is virtually no actions taken to prevent issues or create a documentation overload.

Certain levels of pest activity require additional steps (escalation) to be taken in order to minimize the remaining risks. Levels of pest activity detected should trigger specific responses in terms of additional monitoring, deeper inspections, focused cleaning or chemical application to solve the problem both in the short and long term.

An escalation flow chart or bullet points of what actions are to be taken should be developed and broken into different zones like non-food areas, in the presence of food or inside food or food equipment. Each area will require different actions or urgency based on the risk to the food. It is a good idea to include your PCO or in-house pest management expert when developing thresholds and escalation guidelines.

Here is an example of using additional pheromone monitoring devices as an escalation technique. On a routine weekly inspection the technician records multiple pheromone monitoring devices with insect captures, one of which had a higher rate as depicted in figure 1. As part of the escalation guide, additional monitoring devices were placed out in a grid around the device with the highest capture rate as shown in figure 2. This tactic can help to pinpoint the originating source especially if the initial inspection was unsuccessful in identifying anything obvious. Figure 3 indicates a different area from the initial high count and is where the activity is originating. Unconditioned product, forgotten rework/ hold product, etc. could have been the culprit stored in racking not easily able to be inspected routinely.

This can also prove to be more effective than using a pesticide application as the first escalation action. By locating the originating source, the sanitation, exclusion and pesticide application efforts will be more effective. After some intervention the devices can be monitored to determine the effectiveness of the action. If insects captured decreases to a background level or are completely eliminated, the additional focused monitoring can be removed and the original monitoring program can continue.

Mapping software and technology is advancing to provide more efficiency with interpreting the data. Hot spot mapping and contour mapping (figures 4 and 5) also help to define areas of focus for inspections. The data is represented on a map to display areas of captures indicating a higher probably of the source of the problem could be.

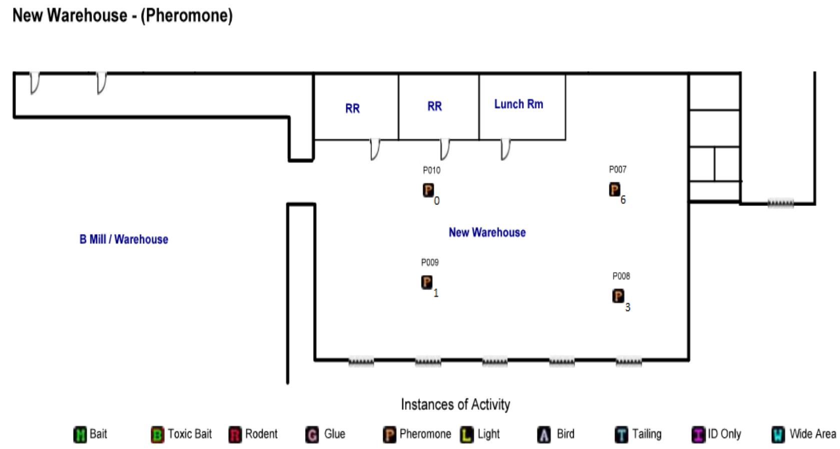


Figure 1. Standard pheromone monitoring layout.

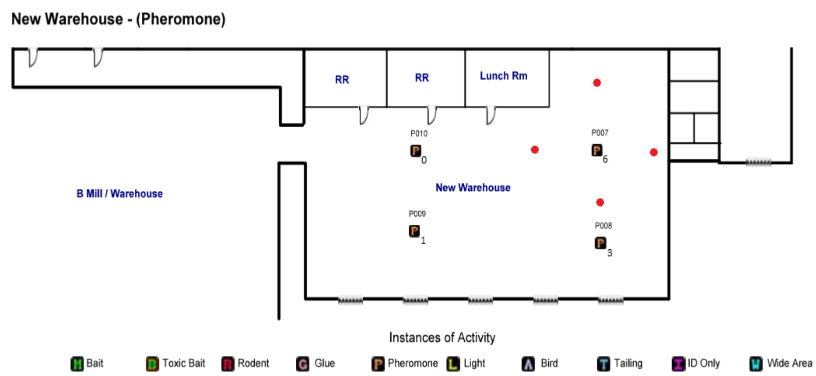


Figure 2. Red dots represent additional pheromone monitors added.

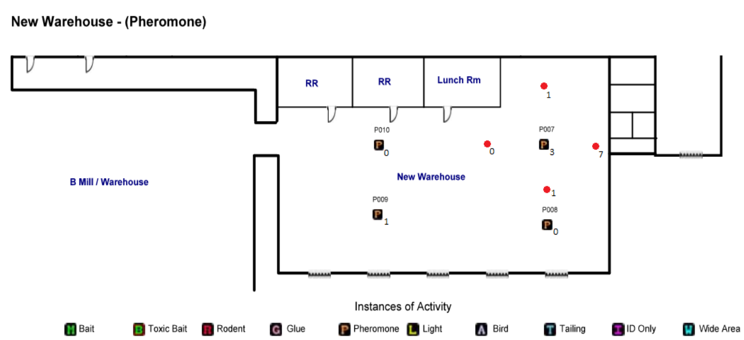


Figure 3. Subsequent captures direct inspection efforts to locate source of activity. Maps were created with U-Trap-It ™ Software.

Periodic Analysis

All monitoring devices need be serviced on a frequency that was outlined in the program design of the facility pest risk assessment. Each device needs to be documented that it was inspected for functionality, cleaned, repaired, replaced and any findings or evidence recorded. Most contracted pest management companies utilize barcode technology to improve the efficiency for recording and interpreting the data. This technology is available for in-house programs, but if other more manual means are being used it should be recorded in a manner that will be easy for interpretation and analysis.

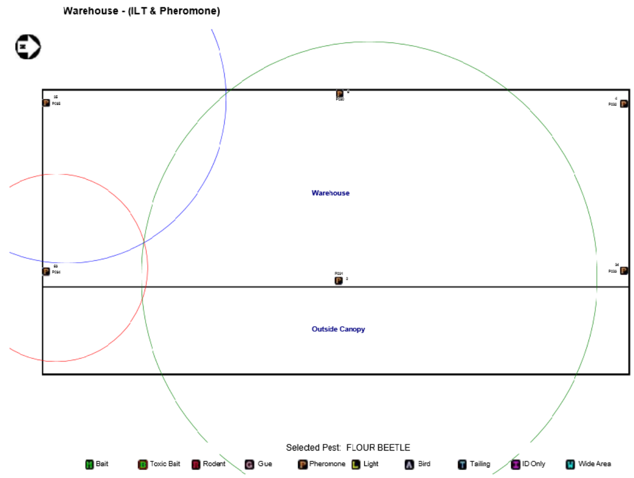


Figure 4. Hot Spot feature integrated into U-Trap-It ™ Software to help define areas to locate source of activity.

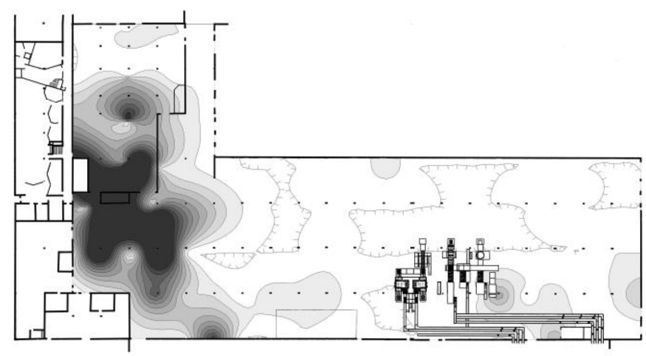


Figure 5. Contour maps of insect captures in traps within a warehouse. The darker the shade of gray, the higher the insect captures in that area, with hatched areas indicating parts of warehouse with no captures. These different patterns suggest different areas to investigate to determine the source of the problem and different pest management tools to use. These maps were made using the program Surfer (Golden Software) with a floor plan layered over top

The methodology behind periodic analysis is not intended to produce a series of graphs and charts to satisfy a food safety audit standard. It needs to be an in-depth assessment of the entire program and its components throughout the year. Common practice in the industry is to perform one each quarter. This process should determine if the program elements are functioning as they were outlined in the facility pest risk assessment, to see if changes to the program need to be made, or through the data see any future trends that could occur and impact the program if not addressed. There needs to be complete objectivity throughout the process and, therefore, should be completed by a pest management expert who is not involved in performing the routine weekly services.

There is not a cookie cutter approach to conducting a periodic analysis as each time it may be different. One school of thought is to analyze the data progressively throughout the year (three months, six months, nine months, twelve month analysis collectively). Another thought may be to just analyze the data in three month increments. Each method will have its benefits and the expert will need to determine the best way for their facility and the significance about the data to communicate. Multiple types of analyses should be performed. See figure 6 for an explanation of the different types that may be used.

The first step of the analysis should be to list all the different pests recorded within a determined frequency. From here, the expert can sort through what is significant or raises an alarm. The subsequent steps will be following additional evidence through review of inspection & pesticide application reports, charts, mapping, physical inspection, interviews of plant personnel, technician, etc. to come up with a conclusion on why the activity is trending the way it is. It is important to draw this conclusion and communicate it so that all parties understand what has impacted any activity, whether in a positive or negative manner.

Conclusions
In order to have a successful IPM program a pest management expert needs to perform a facility pest risk assessment, design a program to mitigate pest pressures, analyze the data and make changes to the program as they are needed.

Periodic Analyses

Guidance
Periodically, an analysis must be performed from a big picture perspective. There are several aspects which should be reviewed to maintain the program's integrity. Following are explanations of the different analyses.

Trend Analysis:

- Increases or decreases in pest populations over time, by season, by trap or area like a seasonal spike in activity, or an increase of activity in a certain area.
- Systematic, procedural, or in the program itself. Examples include:
  - The service technician's reports show there is an ongoing issue which might be considered a trend and may not be documented elsewhere in the program.
  - Deficiencies in sanitation, the condition of the structure, cultural practices, etc. noted during routine inspections show a trend away from fixing major issues or the number of documented issues is growing or shrinking.
  - The FPRA metric may be trending up or down.

Gap Analysis: This analysis should look for any "gap" which might negatively affect the program. The most obvious might be a gap in the trap layout that may be contributing to a pest issue. Another example could be a missing program component like a grain based processor who doesn't utilize pheromone monitoring devices for stored product pests. Other less obvious items may relate to communication, documentation, technology, systems, processes, plant operations, etc.

Efficacy/Needs Analysis: This analysis scrutinizes every element of the program's design. Is the element providing value to the program? Did it outlive its effectiveness? Did the situation that originally existed when the program element was implemented change and now it's not necessary anymore? Each component of the program should be justified.

Quality Analysis: This review simply looks at the quality of how the program is being carried out. Are pest control devices being serviced at proper intervals, cleaned appropriately, etc? Is the information being collected and documented in a useful manner and can you read any hand written reports. The bottom line is whether all of the components of the program are being done and done well.

Update/Upgrade Analysis: The industry is ever evolving. New research, technology, concepts, etc. are being introduced all the time. In order for the program to be at its best, it must evolve also. During the periodic analysis, these new industry developments should be considered and when valuable, added to the program. Additionally, the facility may have changed and is handling different food items, new processes, installed new equipment, have new personnel who need training, etc. The program should automatically adjust to these changes, but periodically it needs to be verified.

Figure 6. Periodic Analyses Guidance document was printed from Assessment Pro integrated with U-Trap-It ™ Software which helps PMPs quickly create comprehensive and professional pest-risk hazard analyses.

Monitoring devices will be the foundation to drive the appropriate strategies and techniques in response to a problem. When evaluating what techniques to employ, the decision process needs to consider what will be the most effective, safest, most economical, most targeted and least disruptive. Using non-chemical means through monitoring, inspection and structural modification, should be used first to identify the source so a permanent solution can be implemented. Simply finding an area with pest activity and spraying insecticides is often going to be ineffective, especially if the insecticide is not getting directly to the harborage site.

For example, in experimental warehouses it has been shown that insecticide applications can result in large numbers of dead adults being observed and reductions in beetle captures in traps, but no corresponding decrease in the total pest population within hidden areas (Toews et al. 2009).

There is a wide range of monitoring and management tools available for stored product pest management in the food industry. Proper design/ selection, effective data collection and thorough analysis of the program will ensure the goals of the overall IPM program are being achieved.

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Toews, M. D., F. H. Arthur, and J. F. Campbell. 2009. Monitoring *Tribolium castaneum* (Herbst) in pilot-scale warehouses treated with β-cyfluthrin: are residual insecticides and trapping compatible? B. Entomol. Res. 99: 121-129.

Toews, M. D., J. F. Campbell, F. H. Arthur, and S. B. Ramaswamy. 2006. Outdoor flight activity and immigration of *Rhyzopertha dominica* into seed wheat warehouses. Entomologia Esperimentalis et Applicata 121: 73-85.

Chapter 3: IPM Components

Section 1c: Managing the Pest Management Company

Contracting a pest management company (PMC) to provide services at a food facility is a common practice in today's food industry. The food facility should have a written pest management program that outlines certain expectations for the IPM program. It should include basic requirements like making sure the following records are current and properly filed:

- Signed contract
- Business and applicator licenses
- Insurance Certificate
- Pesticide Usage Log
- Specimen & SDS Sheets
- Device Schematics
- Pest Observation Log
- Day of Service Reports

In addition to some of the basic examples, the written program should go into more detail about the overall service expectations. Any individual can walk into a food facility, pick up a monitoring device, record the information and provide a document that shows everything was inspected and how many captures. This would be classified as a "trap checking" program, very little detail is being discussed about the findings and what conditions exist that need correction to eliminate or prevent any activity inside the facility.

A food facility needs to ensure it has an "inspection focused" program. Outlining expectations that go above and beyond the basic audit and regulatory requirements will make sure a prevention based approach is executed. Expectations that should be considered to incorporate into the written IPM program are:

- Responsibilities
    - Who owns what; Pest Control Operator (PCO) & Food Plant Personnel
- Thresholds and escalation guidelines
- Expectations on servicing monitoring devices
    - Cleaned
    - Maintained
    - Numbered
    - Labeled, locked and secured if a bait device
    - Non-electrocution style light devices near open food product
    - Replacement cycles on insect light bulbs or pheromone lures
    - Temporary and seasonal devices
- Carcass disposal
- Control strategies
    - Environmental modification
    - Physical and mechanical

    - Biological
    - Pesticides
- Pesticide storage if applicable
- Documentation
- Annual assessment and periodic analysis

For additional resources go to www.NPMAtesting.com where the Pest Management Standards for Food Plants and a comprehensive testing site was developed. This manual was published in 2007 and updated in 2013 by the NPMA to raise the professionalism and technical abilities of the PCO.

The expectations of the food facility for the PMC should be conveyed during the search phase. It is important that the PMC recognize the standards and requirements of a food facility in the areas of food safety, occupational safety, site security and other company standards. The PMC is an integral part of the facility's IPM program and should be an asset.

It goes without saying that the PCO should be familiar with the requirements of servicing the food industry. He or she must understand the legal requirements and industry standards for IPM. Other expectations that should be conveyed are elements of additional food safety programs that may impact the PCO while performing an inspection.

Food Safety/GMPs – The PMC should have a training program for their PCOs. The PCO should have a basic knowledge of the GMPs to limit the concern for introducing possible food safety related hazards. Many PMCs provide basic GMP training to their PCOs upon hire. This and all related training should include a verification activity, such as testing, to ensure the PCO comprehends the training.

Food Safety/GMPs
Specific food safety/GMP considerations the food facility may cover with the PCO could include the following:

- Clothing and personnel attire – Some food facilities require different levels of clothing and attire in different areas of the facility.
- Personnel hygiene – The food facility may have specific areas where a higher level of hygiene is necessary prior to entering. An example may be washing hands prior to entering a packing area from another location in the plant.
- Communicable disease and related topics – This is a broad topic and is also covered in the general GMPs. The food facility may have specific requirements such as all exposed bandages to be replaced with a company specific metal detectable bandage.

Occupational Safety
The PMC should also provide basic safety training for their PCOs. The safety of everyone is of utmost importance. They should not be thrust into an environment where they are unfamiliar

with the facility layout, buildings, and/or equipment. Specific safety considerations may include the following:

- Emergency evacuations routes, alarms, and meeting points.
- Shelter-in-place – Certain emergencies such as natural disasters may require persons to take shelter within the facility. There may be various alarms or notifications and designated sites for shelter-in-place.
- Equipment safety – Grain mills and elevators have some very unique items that are not typically encountered by the PCO in other industrial accounts. These might include grain bins and silos, manlifts, lineshafts, milling equipment, etc. The facility should discuss any site specific equipment that requires further safety training in order to effectively provide Integrated Pest Management services.

Site Security

The PMC should follow the guidelines for security in the Pest Management Standards for Food Plants. Some of the specific suggestions in this manual include background checks of the PCOs, company identification badges, and vehicle security. Specific security considerations the food facility may cover include the following:

- Visitor sign-in and sign-out – It is important for the PCO to register with the site during each visit. This is necessary for access control within the site and to ensure everyone is accounted for within the operation in case of evacuation.
- Visitor identification – The food facility should provide specific visitor ID badges and/or visitor colored hairnets, bump caps, vests, etc.
- Vehicle Security – The PCOs should be instructed where their vehicles should be parked while at the facility, and it is their duty to keep the vehicle secured while unattended on company property. Some facilities choose to provide visitor vehicle identification tags as well.

Summary

This entire chapter is intended to help the food safety committee to develop and execute a successful IPM program whether contracting to a PMC or utilizing trained in-house personnel. It is critical to the success of this program to ensure that goals and expectations are communicated with the PCO's who will perform the services. In addition to having this manual as a guide for setting those expectations, PMC's & NPMA are also good resources to help develop a comprehensive IPM program built with a focus on prevention.

Chapter 3: IPM Components
Section 2: Flour Mill Sanitation

A master sanitation program framework is essentially an all-inclusive list of cleaning tasks and required frequencies for each task that must be maintained in each area and for each piece of equipment to maintain an acceptable level of cleanliness.

In order to develop an adequate master sanitation program or Master Sanitation Schedule (MSS), several key components must be considered.

- What: A complete list of equipment and areas to be cleaned
- How: Written cleaning procedure training
- When: The appropriate frequency for each identified task
- Who: Assign responsibility
- Who: Assign accountability
- Records: Visibility to complete/incomplete tasks
- Communication: Talk about the work
- Inspection: Verification of the adequacy of the program

The program must be a living guide, easily adjustable to meet changing needs. Weather conditions, products produced, and process changes can render what used to work well no longer effective. The format should be flexible enough to either increase or decrease frequency to meet the true need of the program. This flexibility will insure the best use of resources to maintain sanitation goals.

Communication with accountable individuals is the key to success. Only those who actually perform the sanitation tasks and conduct frequent inspections can tell you if the established frequencies are adequate for your standard of clean.

The actual layout of your program can vary from the standard grid form, such as wall charts to Excel spreadsheets to electronic inputs into software such as Task Management and ALM. Choose the option that works best for your organization.

System Cleanouts
With reduction in the availability of effective fumigants, we find ourselves faced with cleaning equipment more frequently than in years past. These deep dives into equipment are referred to as a System Cleanout.

A good place to start with system cleanout is a thorough inspection. Inspect with a frequency that would interrupt insect life cycles in the interior of equipment. If your inspection finds no product build up, consider increasing the inspection to a longer period, conversely, if product build up is apparent at each inspection, you may want to consider more frequent inspection if results dictate. Continue this effort until you either establish an appropriate cleaning frequency or until you know that the area is not a concern. Address the equipment in your program accordingly. Adding an area to your program is actually the last thing anyone wants to do. Look for the root cause of a sanitation need and work to eliminate that need. Be sure to inspect and clean with enough detail. For example, if the current level of cleaning is not adequate to control stored product pests - dig deeper. Inspect and clean hard-to-access areas such as inside spouting, especially spouts with square corners, when present. Cameras with flexible 3' heads are common and available at most hardware/home improvement stores.

Also, consider if there is a possible engineering solution to the problem. Perhaps there exists an overdue, permanent solution to a temporary repair.

Master Sanitation Schedules

A good way to develop a Master Sanitation Schedule is to establish a list of areas that will be broken down into specific tasks. A cross-functional team tour of the entire plant is a good way to begin.

Start by making a basic list of areas that contain items needing cleaning at a routine frequency. Include both interior and exterior areas.

This will be the organizational framework for more detailed task listing, especially:

- Exterior grounds
- Raw grain receiving (rail, truck, etc.)
- Storage elevators (Elevator #1, #2, etc.)
- Cleaning house
- Tempering house
- Mill (break out into milling units if more than one)
- Bulk storage
- Bulk load-out
- Packaging
- Warehouse
- Maintenance areas
- Mechanical areas

When all major areas have been identified, begin compiling lists of specific tasks for each area. Once again, use a cross-functional team and be sure to include at least one person who is responsible for cleaning, as he or she often has knowledge of what needs cleaned and how often. Each task name or description should include a verb that gives action to and describes each task. If an electronic tracking program is being used, this may be a built-in option. For tracking purposes, it is helpful to designate each task as a “Structure” or as “Equipment.”

Under structure, include areas such as exterior roofs, interior overhead ledges, supports and ceilings, floors – broken down by floor, room, or as needed to aid in scheduling and tracking. Also, include walls and floors, pits, stairwells, mezzanines, bulk bins, freight elevator shafts and pits, etc.

The equipment list should include each type of equipment found. *Note: Detailed parts or sections of equipment may be better noted and broken down in written cleaning procedures for each piece or task.* Again, tour every building, area, and floor, listing each piece of equipment as you go.

It often makes sense to list equipment by type where there are multiple pieces. Every facility will contain different equipment (*e.g.,* grain elevator legs and boots, dust filters, environmental air make-up rooms, ducts and shafts, product spouting, dust trunk lines and spouts). Equipment to consider in a System Cleanout scenario includes:

Roll stands	Salina valves	Packer bins
Purifiers	Splitters	Packer sweeps
Sifters	Vertical spouting	Packer scales
Dusters	Scales	Palletizer carousels
Mill filters	Hoppers	Packer suction
Screw/Drag conveyors	Storage bins	Bag conveyors
Suction lines	Loadout spouts	Bag magazines
Horizontal spouting	Gasket material	Bag filling spouts
Bucket elevators	Hose manifolds	Aspirator ducts
Trunk lines	HVAC ductwork	Blow out panel areas
Elevator boots	scales	

When Should the Tasks be Completed?

Once the task list has been compiled, frequencies need to be established for each task. Ask the question: "How often does the task need to be completed to maintain the desired level of sanitation?"

Most cleaning can be grouped into types:

- Period cleaning – Includes tasks scheduled at frequencies of 8 days or greater.
- Routine cleaning - Includes those tasks completed at frequencies of weekly or more frequent.

In areas where insect harborage is a concern (such as conveyor interiors), period cleaning frequencies should be set no longer than monthly. Twenty-eight days is a good place to begin. Sanitation and equipment clean-outs completed monthly or more often can be an effective integrated pest management tool in the control of stored product insects. Routine cleaning or housekeeping tasks should be scheduled at frequencies required to maintain an overall acceptable level of visible sanitation. Such tasks include daily sweeping and vacuuming.

How Should the Program be Established?

Written cleaning procedures must be created for each cleaning task. The list of cleaning tasks for a flour mill can be quite large, however, at times a single, written procedure can be used for more than one piece of equipment or area (*i.e.,* it may be appropriate to use the same screw conveyor cleanout procedure for screw conveyors located in different areas – as long as the steps required to clean are the same). ***Caution:*** **When one procedure is used for multiple pieces of similar equipment, be sure any differences in safety prerequisite requirements are captured for each piece.** Refer to specific facility safety programs when appropriate to ensure all aspects of required safety are covered. Be sure the references to safety programs and any safety-related specifics are acceptable to the facility safety manager.

Cleaning procedures often include:

- A description of the task and the desired results
- A list of equipment and supplies required
- Personal protective equipment and safety requirements
- Step-by-step cleaning instructions
- Final inspection of results
- Clean-up and documentation requirements

Procedures should contain enough detail so that an employee with a general knowledge of cleaning can use the procedure as a guide and obtain acceptable results. **Please note that persons cleaning must be trained and follow the written procedures used as part of the training.** Documentation of cleaning procedure training should be maintained for each employee.

Who Should be Involved?
Determining who will manage and who will complete the cleaning is often where a good sanitation program can fail. It's important that the plant management staff supports the cleaning program by ensuring those responsible for scheduling and completing the cleaning are held accountable. The facility management staff should establish overall plant sanitation task completion goals and review the completion rates on a routine frequency – such as monthly. Anytime sub-standard completion rates are observed, corrective actions need to be implemented. Management must ensure that adequate plant/equipment downtime is available to facilitate cleaning.

Inspection
Once the task list, frequencies, and written procedures have been established, the results of cleaning must be inspected. If the results are not acceptable, the frequency and/or procedure need to be modified and trained against until acceptable results are consistently obtained. In the case of equipment clean-outs, sifter tailings should be monitored to help determine if the procedure or frequencies are adequate. Insect evidence in sifter tailings is a good indication that the procedure or frequency is inadequate or something is being missed.

Records
Complete records of cleaning are essential. There are numerous ways to document and track cleaning task completion – from basic, hand-written forms and Excel spreadsheets to detailed software-tracking programs. Regardless of the documentation method used, it is important that it be appropriate for the facility and as user-friendly as possible. In addition to documenting and

providing data for completion rate reporting, a good tracking program will also help keep the sanitation program on-track by generating the cleaning task prompt from a pre-set frequency or by providing a visual spreadsheet. Be true to the old saying, *"If it wasn't documented, it wasn't done"*.

Communication

Sanitation in grain storage and milling facilities can be a complicated process that involves numerous people over multiple departments and shifts. For a well-structured sanitation program to be successful, it is important to communicate the facility results to all levels of management staff and employees. In addition to routinely posting and discussing sanitation program results, two-way communication with the people cleaning is critical to continuous improvement.

Chapter 3: IPM Components

Section 3: Physical Controls – Sifters and Impact Machines

Even though a plant may have a robust IPM program of inspections, sanitation, and chemical usage, in a large bulk grain process it is nearly impossible to achieve 100% control of stored-product insects in the product. Most mills use a variety of sifters and impact machines to remove or destroy the different life stages of insects.

Sifters

The sifting or screening of material is an effective way of removing insects and other foreign material from dry powder or granulated product. All sifters operate on the same principle. They contain one or more mesh screens or cloth with specific sized openings. Product is passed over the screens and falls through. Any material larger than the opening is separated from the product. The size of the screen opening depends on the particle size of the product being sifted and the flow rates desired. There are three different types of sifters.

Types

Plansifter:

Plansifters are large boxes that contain a stack of sieve frames. A screen/cloth is stretched over the frame. The entire box is suspended from the ceiling or frame which allows it to "shake" in a small circle. Product enters at the top and the motion moves the product back and forth over each sieve in the stack. At each pass, some product goes through the screen and directly out of the box. This continues on each sieve until the last sieve. At this point any material larger than the screen opening size is separately discharged out of the sifter.

Plansifters are typically used in flour mills and loadout systems where a large flow rate is needed. They are also very gentle in their separation meaning that breakage of foreign material and product is minimized. However, inspecting the screens for holes requires a complete tear down, and takes a significant amount of time. If not maintained properly, they can be a harborage area for insects.

Vibratory:

Vibratory sifters are very simple and typically consist of a single screen and frame with a vibratory motor. Product is placed on top of the screen and passes through it. Material larger than the screen opening remains on top or is vibrated off the side of the screen. Vibratory sifters are typically used for low volume feed in areas. An example of this is when adding bagged or small containers of ingredients to a mixer. They are simple to operate and screen holes are easy to find. They are not designed for high flow rates.

Rotary Sifter:

A rotary sifter consists of a screen stretched around a stationary cylindrical cage. Within this cage are rotating bars or paddles. Product enters one end of the cage. The rotating bars convey the product inside the cage across the screen. Centrifugal force causes the product to pass through the screen and outside of the cage. Material larger than the screen opening carries off the end of the cage.

Rotary sifters can be used for final product sifting. An advantage is that the screen can easily be checked for holes. Frequent inspections are needed as these sifters are more prone to holes due to their rotating parts. Another disadvantage is that the rotating bars can break up foreign material and insects causing them to pass through the screen.

Location in Process for Insect Control

Mill Rebolt/Redress Sifter:
All flour mills typically have a "redress" sifter at the end of the milling process just prior to bulk storage. Its primary purpose is to clean up the flour by removing any bran or unground endosperm that may have passed through the milling process sifters. This sifter, followed by an impact machine, (see below) is effective at controlling insects in the bulk storage tanks.

Ingredient Receipt:
Locations that receive bulk ingredients should sift these ingredients prior to unloading into the storage tanks. This is especially important if product is returned from customers or received from other sources.

Ingredient Addition:
All ingredients should be added to product prior to its final sifting. This ensures that bagged or boxed ingredients get sifted. Some finished products such as bakery mixes cannot be properly sifted due to the added fat or granular ingredients such as whole grain flour. In this case, ingredients should be sifted, whether bag or bulk, just prior to the mixer.

Final Rebolt/Final Product:
The most important product sifting occurs just prior to the final transfer to the packing bin or bulk vessel. This is a mill's last chance to remove any foreign material (including insects) before delivery to a customer. These sifters are often called the final rebolt sifter.
This sifter should not be considered an insect removal device. It is not a replacement for proper sanitation in the process. The final rebolt sifter should be used as a monitoring tool. See the tailings section below. (Link to/from IPM applications for processes – Transfer and loadout bins)

Sifter Screen Opening Sizes

The size of openings in the screen that the product passes through is a very important factor for insect control and product quality. Opening sizes depend on the product's granulation requirements and desired flowrate.

Sifter screen opening sizes are often referred to as mesh sizes. The mesh size refers to the number of screen wires/threads strands per inch. The higher mesh size number the smaller the opening. Typical mesh sizes for white flour final rebolt sifter range from 30 to 40 mesh (450-600 microns). This is sufficient to remove all adult stages of common stored product pests. However, eggs and larvae may pass through.

To remove all life stages of stored product pests, a 150 to 180 micron screen opening is needed. Using this size opening substantially increases the amount of screen surface area needed to maintain the desired flow rate.

Tailings Monitoring
Tailings is a term for the material that does not pass through the sifter screens and "tails" over or remains on top of the screen. Tailings should be collected in a container so they can be inspected. Tailings should be checked at a defined frequency. Final rebolt sifter tailings are typically checked after every load or at least once per shift. Inspecting tailings not only identifies potential foreign material issues, it can be an effective monitoring tool for identifying insect issues in equipment prior of the sifter.

Abnormal findings in tailings should be clearly defined and action threshold levels set. As stated above, it is nearly impossible to achieve 100% control of stored-product insects in product. Thus, an action threshold for insects in tailings is very difficult to establish and depends on many factors. For example, insect counts may spike for one load as small pockets of insects that work their way through the system. The insect counts may not even correlate with the bins previously used as insects can remain in the sifter and carry over to the next load's tailings.

Plants should use the presence of live insects in the tailings as a general indicator to determine if there is a hot spot in a bin, and to some extent to determine when additional IPM methods are needed such as bin cleaning and fumigation. Due to safety concerns and continuous operations, it is not feasible to clean or fumigate bins immediately after a hot spot is discovered. Ensuring that a suspect bin is completely empty prior to refilling is a simple way to help control insect populations in a storage bin.

Impact Machines
Impact machines are also a valuable tool for infestation management. They are often known by other names such as: Entoleter, Simpactor, Infestation Destroyer or Impact Mill.
Method of operation – impact.

Impact machines have been used in flour milling for many years to control internal grain infestation and to destroy insect eggs. They operate by using a set of spinning rotors and pins. Material enters the machine at the center and is accelerated by the rotors towards the stationary outside wall of the machine. This "impact" destroys insect eggs and breaks open any grain that may have internal infestation. The internal infestation can then be aspirated off.
The pins and rotors will wear, and need replacing on a set frequency. This frequency depends on the abrasiveness of the product. Ones used on grain will wear much faster than ones used on flour.

Impact machines should not be used on products with specific granulation requirements, such as farina, grits or semolina. Particle size of these products will be reduced by an impact machine.

Location in Process
Cleaning House:
Impact machines with aspiration are typically used in the cleaning house to break open any unsound grain and remove internal infestation. Some impact machines also "scour" or abrade

the grain. This effect (with aspiration) aids in the removal of dust, mold and insect stages that may adhere to the kernels or under loose pericarp.

Mill to Storage:
Many flour mill operators install an impact machine for flour at the last point in the mill just prior to bulk storage.   The purpose is to destroy any insect eggs that may have passed through the mill sifters and to prevent infestations in the bulk storage bins.

Loadout:
Impact machines are very often used in the final flour transfer systems from the bulk storage to the packing and bulk loadouts.   Ideally, the machines are placed after the final rebolt sifter to destroy any eggs in the product. Because of their speed and needed flowrates, impact machines in this application typically require large (50+)horsepower motors to operate.

Effectiveness
Impact machines should be operated at their designed flowrate and RPM. Additional product can create a “cushioning” effect which reduces its effectiveness.   Operating at a reduced speed will also limit the desired results.

It is also important that 100% of the product passes through these machines. Spouting bypasses either for product or aspiration should be avoided.

Although impact machines are very effective at destroying insect eggs when properly operated, they should not be viewed as 100% effective. As with sifters, effective IPM methods must be implemented throughout the process.

Chapter 3, IPM Components

Section 4: Chemical Controls

Introduction

Insecticides used for insect pest management in mills and warehouses include spot treatments with fumigants, aerosols, contact insecticides used as residual surface treatments, and crack and crevice or spot treatments. These are best considered as individual control tactics, and hence each must be defined. Spot fumigations are limited fumigations of specific equipment or areas that are sealed within a facility or sealed/secured trailer parked on the property where the fumigation will occur.

In the past, methyl bromide (MB) or the labeled formulations of the fumigant phosphine (Phostoxin), cylinderized phosphine (Eco2Fume) have been used for whole-plant and spot treatments. While methyl bromide fumigations can be done within 24 hours, phosphine use takes more time. A minimum of 34 hours is needed with Magtoxin (magnesium phosphide formulation) at temperatures of 80°F or above when used for spot fumigation of empty equipment or 72 hours when using the aluminum phosphide formulation. Aluminum phosphide fumigations at 60°F to 80°F can take up to 120 hours. The fumigant sulfuryl fluoride (SF), under the trade name Profume®, has been introduced and labeled for use in the United States and in many other countries as well. It was originally registered by DOW AgroSciences, but in 2015 the marketing rights were sold to Douglas Products (www.douglasproducts.com, Liberty, MO, USA). Dosage rates for SF are calculated through a specific computerized program the Fumiguide®, which calculates dosages based on a wide range of variables, including but not limited to temperature, the structure, and the target insect species.

Label directions for MB, phosphine, and SF must be followed as certain minimum temperatures will need to be attained and exposure time adjusted for maximum effectiveness. These fumigants are toxic to any living organisms "trapped" within the sealed area under fumigation whether pests or otherwise. Their use also requires the use of personal protective equipment for the fumigators. Any aeration requirements will be explained on their respective labels. Labels will also explain dosage rates that must be met to assure adequate toxicity to all life stages of stored product insects. While very effective when properly done, general / structural and spot fumigations must be approached with caution due to the toxicity of the fumigants. Their use normally requires the applicator to be "licensed or trained," so they should not be used before checking state and/or local laws. Spot fumigations, along with any use of fumigants in or around a food plant, are normally contracted out to a licensed pest control operator due to label requirements for application of fumigants.

Aerosols are liquid insecticide formulations that are mechanically atomized and dispensed as small particle sizes of 5 to 50 microns. They are also known as "mists" or "fogs", but here aerosols will be the term used in this chapter. Aerosols can be applied using fixed or portable dispensers, and are usually applied on a per-volume basis inside a structure. Most formulations have an oil-based carrier along with a propellant to aid in dispersion. Aerosols do not penetrate materials and should not be confused with fumigants. Fumigants are toxic in the gaseous phase, and will penetrate throughout structures. Fumigants and heat treatments will be fully discussed in other chapters of this IPM manual, and this chapter will focus on spot fumigants, aerosols, and contact insecticides.

Residual treatments will include those insecticides that can be applied to a large, broad flooring area of a mill, warehouse, or processing facility, or as a crack and crevice or a spot treatment. In the United States, the labels for these insecticides will specify their use as a “general surface treatment”, or with specific wording limiting that product to a crack and crevice or spot treatment. In that instance, the spots will be restricted to a defined area, for example 2 ft^2 (0.09 m^2), with a restriction on the total area that can be treated in this manner, or the wording will state that the spray must be directed inside the crack or crevice. There are a limited number of insecticides that can be used as surface treatments compared to crack or crevice or spot treatments. However, many of the characteristics regarding potential efficacy of residuals will apply regardless of their specific usage pattern. In this chapter, we will give some specific examples of research with residual insecticides.

A list of references will be provided at the conclusion of the chapter; however, inclusion of specific references does not necessarily imply importance or significance. These references are listed for readers who want to pursue additional information.

Spot Fumigation

Spot fumigation is the fumigation of specific, targeted pieces of equipment or areas. It may be considered a routine treatment option to supplement prerequisite programs such as sanitary design, preventative maintenance, and periodic cleaning programs. When planning a spot fumigation, it is important to realize that the fumigation will only be effective in areas where gas concentrations can be held at lethal levels for the length of time specified on the product label. The goal of any fumigation should be to kill 100% of all insect life stages. The effectiveness of spot fumigation is dependent on proper sealing and cleaning of the target area. Spot fumigation is intended for treatment of areas and equipment without product or significant product residue and should not be considered for commodity fumigation. Specific components of spot fumigation will be addressed below.

Planning the spot fumigation

Before setting up a spot fumigation, a detailed sanitation inspection for stored product insects should be done. The inspection should include all areas of the facility from exterior grounds through receiving, storage, processing, product transfer, packaging, load out, and shipping. The purpose of the inspection is to identify areas of the facility grounds, structure, and equipment where infestations of stored product insects could persist due to the accumulation of product, dust, and/or debris. If these infested sites are not identified, the fumigated area may be re-infested shortly after treatment. When inspecting, identify areas or systems where pests may harbor, then systematically inspect each area inside and out to identify specific locations where grain, dust, product, or debris may accumulate. Particular attention should be paid to any capped-off spouts, dead ends and idle equipment, and bins or hoppers with bridging or accumulated product on the sides or corners. Once points have been identified, determine why they exist. Either re-design the area to eliminate the problem or address tools and procedures needed to alleviate the problem. Include all identified areas on the facility master sanitation schedule with minimum cleaning frequencies (usually at least every 4 weeks) to disrupt stored product insect life cycles. Insects must be identified and cleaning frequencies adjusted as needed. Remember, “Sanitation IS Pest Control!”

The most commonly used spot fumigants are the phosphine products, available in several different solid and gaseous forms. Sulfuryl fluoride, while more commonly used for structural fumigations, can also be utilized for spot fumigations. Gaseous fumigant products may be packaged in gas-containing metal cylinders or generated on site using specialized equipment. Gaseous fumigants are most appropriate to spot fumigate equipment that can be tightly sealed, such as bins and other vessels. While a label may permit the use of gaseous fumigants in leaky equipment, the use of such a fumigation technique is discouraged as it will likely require significant labor for monitoring and gas addition which adds expense. Such a practice may also contribute to a “poor” fumigation with incomplete toxicity to all insect life stages which can add to insect resistance issues. Gaseous phosphine, when applied to equipment that is tightly sealed and when temperatures are between 80° and 90°F can lead to shorter minimum exposure times because there is no time needed for the solid form of phosphine to “break-down” and release the gas. Solid fumigants are produced in magnesium phosphide and aluminum phosphide formulations and are available in a variety of packaging options. Solid fumigants release phosphine gas over an extended period of time, and tend to be more effective for spot fumigations when some gas leakage is anticipated. Solid fumigants should be chosen based on the size of area to be spot fumigated, temperature, and available length of exposure period. Some magnesium phosphide fumigants, such as Magtoxin, have shorter minimum exposure periods due to faster release of gas based on formulation and package size. Consult an experienced fumigator and the product labels to determine which product is best for each application.

Often, spot fumigations are performed within a limited amount of facility down time, and therefore, pre-planning is essential. Spot fumigations must never be done in or near occupied areas. The spot fumigation must be planned well in advance to allow time for the following:

- identification of equipment to be fumigated
- pre-cleaning plans
- disassembling of equipment
- sealing requirements
- dosage calculations
- application worksheets
- plant safety planning

Before the fumigation can be done, a detailed, written “FMP” or Fumigant Management Plan is required in accordance with the label. Walk through the facility and create detailed sealing checklists that describe each piece of equipment to be sealed, what type of seal, (*i.e.*, tape, plastic sheeting, etc.), will be required, and where the seals need to be placed. It may be necessary to break and seal some spouts, pipes and ducts to contain gas in areas designated to be fumigated. All equipment to be spot fumigated should be listed on a fumigant application worksheet. In order to ensure all fumigant packages placed inside equipment are removed following the exposure period, the worksheet should include check areas and initial blanks for “dosage in” and “dosage out”. It is not uncommon to spend two to three weeks or even more to plan a spot fumigation for an average-size mill. It is important to work with a fumigator who is experienced using spot fumigants, since inadequate identification of equipment to be fumigated or poor dosage and or sealing could result in unacceptable fumigation results or possibly lead to insect resistance to phosphine. An aerosol application can often be done along with the spot fumigation. Aerosols will be discussed in more detail later in this section.

Preparing for the spot fumigation

Fumigants are lethal and safety is critical; therefore, no one must be permitted in or near any areas to be fumigated. Notices must be distributed in advance and include everyone, including potential contractors, janitorial and vending suppliers, and truck and rail services. Environmental pre-cleaning, including cleaning of overheads and equipment internal and external cleaning, should be completed before the spot fumigation. Before and as the facility is “shutting down”, ensure all dust trunks and spouts are clear with no chokes. Other details include:

- Allow equipment to run as long as needed after the grain load is taken off to permit sifters, roll stands, filter hoppers and other equipment to empty out.
- Empty choke bins, in-house vacuum systems and hand carts.
- Once equipment is shut down, walk each floor/area to visually inspect for final cleaning and preparations that may be needed.
- Manually open and remove product from inside equipment that does not completely empty-out (*e.g.*, screw/auger conveyor bottoms, filter hopper bottoms, spout walls, roll stands, product hoppers and drag conveyor ends).
- Remove cloth breather bags and socks and place in bags or containers for spot fumigation, or if new bags are planned to be installed, discard outside of the facility. It does little good to fumigate a bin or piece of equipment only to re-install an infested bag or sock.

Using the sealing checklist, seal all equipment and areas as needed. Before the spot fumigation, applying crack and crevice contact and or residual insecticides throughout the facility, where allowable by label, company and not restricted by product types (*i.e.*, natural or organic), can aid in the overall effectiveness of the treatment. If live insect test cages are to be used to verify effectiveness of treatments, place them at this time.

Exposure period

The fumigators must follow all safety requirements as required by the label. The must also ensure the necessary emergency and security personnel have been notified and that all people have left the area. Before application of fumigants, investigate any unknown vehicles on the premises and verify the location of the owners. Place fumigation placards on entry doors and secure all entrances as required by label and site FMP. Utilize monitoring equipment and PPE designed for the specific fumigant any time fumigants are handled and during aeration. Using the fumigant application worksheet, apply fumigant per pre-determined dosage, to each designated piece of equipment and area. Be sure each fumigant package is secured so it cannot fall out of reach into equipment, and be sure it is clearly marked for easy retrieval at the end of the fumigation. As each piece of equipment is fumigated, the fumigators should double-check that seal and sealing methods are adequate to contain gas. The fumigator in charge must monitor gas concentration over time as planned to ensure the fumigation is effective.

Post-fumigation
Following exposure as specified by the product(s) label and using appropriate personal protective equipment (PPE), the fumigation crew must remove all fumigant packages applied. The fumigant application worksheet should be used to verify and document removal of all fumigant packages. Next, aerate equipment and areas until detectable gas levels are at or below levels acceptable for the fumigant label used. Document all verification of gas testing. Following aeration, collect insect test cages and evaluate for treatment effectiveness. These test cages should be monitored for several days to monitor any delayed mortality resulting from exposure to the fumigation. Inspect treated areas for signs of dead and/or live insects. Dead insects on the floor or equipment are an indication of a treatment, but more important, they may also help identify opportunities for sanitation or sanitary design improvements. Live insects are often a sign that the equipment spot fumigated was not sealed adequately or was improperly dosed. Spot fumigation is often a learning process; therefore, knowledge gained from an individual spot fumigation must be applied to improve sanitation and fumigation techniques the next time a spot fumigation is done.

General / Structural fumigation
Insect activity in a structure / building / equipment can be eliminated by general - structural fumigation of the entire building. Structural fumigations are effective to treat equipment, piping and all areas inside the fumigated area – when all equipment and properly pre-cleaned and opened to allow the gas to penetrate. Sulfuryl fluoride can penetrate flour, wheat and production dust, however, structural fumigations are not commodity fumigations and may not be effective at penetrating product. Product, ingredients and build-up of such materials must be removed from all areas – including equipment internal areas prior to the fumigation. Structural fumigations are performed by sealing all exterior ventilation inlets / outlets, exhausts, doors and window cracks and any other openings as needed to effectively contain gas in the building or structure for the intended exposure time. Sulfuryl fluoride, is currently one of the most common fumigants used for structural fumigations. The use of SF in a fumigation program may also be helpful to limit the development of insect resistance to other fumigants, such as phosphine. Application, use and monitoring of sulfuryl fluoride requires specialized fumigant training, planning, and monitoring equipment. As with all pesticides – it's critical that the fumigant label is thoroughly understood and followed through the entire fumigation – including planning. *Temperature of the fumigated areas and structures within are critical. It may be necessary to include supplemental heating for fumigated areas to ensure temperatures of fumigated areas and structures do not drop below minimum temperatures required by the fumigant label and computerized Fumiguide® program. Temperatures should typically be maintained at 80 degrees F and above. Cooler temperatures require longer exposure times, higher gas concentrations and may result in a less effective fumigation. Stored product insect eggs located in areas with temperatures below required minimums may not be killed. The "spot fumigation" guidelines outlined in this IPM Manual,

may be useful for structural fumigation planning. The fumigant application manual must be strictly followed.

Aerosols

Factors affecting efficacy

There are currently a number of commercial manufacturers in the United States that have their own proprietary aerosol dispensing systems and formulations. As mentioned earlier, aerosols should not be confused with fumigants, as they are not toxic in a gaseous stage. They do not penetrate materials, and they are generally used to control insect pests in areas that are open and accessible to the aerosol. Smaller particles generally have better dispersal indoors into smaller areas and harborages, and they suspend longer in air before settling. More detailed information on aerosols can be found in the chapter references. In addition, specific information regarding the biology of pest insects can be found in Chapters 2-5 in the book Stored Product Protection by Kansas State University (see References).

With the impending elimination of methyl bromide, there is increased interest in use of aerosols in flour mills, food warehouses, and food production facilities. Some of the factors that affect efficacy of insecticidal surface treatments, such as the presence of food material, also affect aerosol efficacy. The presence of food material, either during or after exposure to pyrethrin aerosol, will greatly increase survival of exposed adult red flour beetles or confused flour beetles, even if the aerosols disperse into the areas containing the food material. Also, aerosol dispersion within a mill may be affected by equipment and other barriers that obstruct dispersion. Infestations may persist in these sites that are not being reached by the aerosol, and the additional presence of food material may reduce insecticidal efficacy.

Aerosols and target insect pests

There are several formulations of natural synergized pyrethrins or pythroid aerosols available for use inside interior structures. Dichlorvos (Vapona, DDVP), is also used as an aerosol. It has excellent vapor toxicity and dispersal ability and gives intitial control of all insect life stages but offers little or no residual control. Often, either methoprene or pyriproxyfen Insect Growth Regulator (IGR) is added to the formulation, primarily for residual control of the immature stages of insect pest species. Although aerosols have not been traditionally associated with residual control, the IGRs are changing that assumption. Identification of the specific beetle species is important when considering which insecticide to use for a particular situation. For example, red flour beetles may be more susceptible to the methoprene than confused flour beetles. Aerosols have also been evaluated for control of immature stages of the Indian meal moth, widely considered to be the most important pest of stored processed food in the United States. Mature larvae are difficult to kill with conventional insecticides compared to stored product beetles, but they are susceptible to IGRs. The addition of methoprene IGR to a pyrethrin or pyrethroid aerosol contributes little to the overall cost, yet greatly increases aerosol efficacy. Another group of insects to consider in a mill or warehouse is psocids, which is a group of insects that appear to be an increasing pest problem. Psocids are much harder to kill with contact insecticides, IGRs, and aerosols compared to stored product beetles. Individual psocid species will also vary in their susceptibility to insecticides.

Residuals

Factors affecting efficacy

There are only a few insecticides labeled for use as a general surface treatment, while more are available as crack and crevice or spot treatment. For specific directions regarding applications, users should consult the label for a particular insecticide to determine allowable concentration, frequency of application, specific application methods, and target pest species. Labels are legal documents requiring compliance with federal and state laws. Many factors affect efficacy of residuals, including but not limited to the specific surface substrate, insecticide formulation, temperature, and target insect species. Residual insecticides generally have low persistence on porous surfaces such as concrete and wood, but sealing or painting these surfaces prior to insecticidal applications can extend efficacy.

Different formulations of insecticides may also vary in efficacy on different surface substrates. For example, emulsifiable concentrates generally have less persistence on porous surfaces compared to wettable powders. However, formulations of some insecticides have changed. For example the insecticide cyfluthrin (Tempo®) is now marketed as an SC Ultra formulation, and the emulsifiable concentrate and the wettable powder versions of this insecticide are not readily available. In addition, there are many new formulations and insecticides used for crack and crevice or spot treatments, and older recommendations and guidelines may not be applicable in each and every situation. Temperature will also affect residual efficacy. Efficacy of pyrethrins and pyrethroids is normally negatively correlated with temperature, and efficacy of most organophosphates, diatomaceous earth (DE), and the insecticidal pyrolle chlorfenapyr is usually positively correlated with temperature. However, effects are often variable, and specific insect species can vary in their susceptibility to an insecticide or a class of insecticides. For example, red flour beetles and confused flour beetles are generally more difficult to kill compared to most common stored product beetles.

Sanitation and efficacy

Perhaps the most important factor in assessing residual control is the presence of food material, either during the time a stored product insect has been exposed to the insecticide or afterwards. Many recent studies show that survival of adult red flour beetles or confused flour beetles exposed to a residual insecticide increases when those beetles are provided with a food source. Accumulations of spillage material or by-products associated with the milling process can provide harborage sites where infestations can persist. The presence of refuge sites can limit effectiveness of residual insecticides when they are used for controlling adult insects. The presence of dead adults after a treatment may not be an accurate indication of treatment effectiveness, hence cleaning and sanitation is an important component of the overall pest management program.

Insect Growth Regulators

The other broad general category of surface treatments used to control insect pests in interior structures is IGRs. In the United States, hydroprene (Gentrol®), methoprene (Diacon II®), and pyriproxfen (NyGuard®) are all registered for use as general surface treatments. These IGRs will not kill adult insects; they instead affect growth and development of immature stages, and should considered more for long-term population control than immediate reduction of an infestation. Of the three IGRs mentioned above, hydroprene is generally volatile and may not give residual control comparable to methoprene or pyriproxyfen. The characteristics of the treated surface and insecticidal formulations described above will also apply to the IGRs; however, the presence of food material is necessary to evaluate the effectiveness. If a surface is treated with an IGR, food material can be deposited on that surface. Adult beetles will generally lay eggs in food material and hence will be exposed to the IGR if it is absorbed from the surface into the food. Flour can also absorb residues from conventional insecticides that are applied to flooring surfaces.

Summary

This chapter focuses on use of spot fumigations, aerosols, and residual insecticides as components of pest management plans for the milling industry. Some of the factors that affect insecticidal efficacy were discussed in relation to pest management programs, including the importance of cleaning and sanitation in conjunction with use of insecticides. Individual facilities will have specific characteristics that must be considered in developing a pest management program, which may influence their choices regarding timing and frequency of chemical interventions.

The publication, Stored Product Protection, by Kansas State University (see reference) will be useful for further study.

Acknowledgements

Information reported in this chapter is for educational purposes only. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture (USDA), Mondeléz International, General Mills, or the International Association of Operative Millers. The USDA is an equal opportunity provider and employer.

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Chapter 3: IPM Components

Section 5: Using High Temperatures (Heat Treatments) for Stored Product Insect (SPI) Management

The use of high temperatures or heat treatments is not new to the food or milling industries. It was used in the early 1900's to kill stored product insects in flour mills. While effective, it was found by trial and error that equipment/structures could be damaged and it was difficult to maintain temperatures between 50 and 60°C. Early flour mills were built with a great deal of wood within the structure and flooring, and repeated exposure to temperatures of 60°C or greater caused warping and cracking. In some mills the lack of adequate heating capacity resulted in attaining temperatures that were not lethal to SPI (less than 50°C). The mill and food plant construction materials/techniques improved moving through the 1900's, but the discovery of effective and cheap fumigants like ethylene dibromide, carbon tetrachloride, and methyl bromide shifted the focus away from heat treatments to actual fumigations for SPI control. Now with the phase-out of methyl bromide, heat treatments are becoming popular again.

The intent of this chapter is to give you a broad understanding of how heat treatments can and should be part of an integrated pest management strategy, where applicable, and to provide links to already published scientific articles on efficacy of high temperatures against certain SPI.

Heat Treatment

Heat treatment involves raising and maintaining temperatures of grain storage structures, warehouses, and food-processing facilities between 50 to 60°C to manage stored-product insect species. The duration of heat treatment is application-specific and may vary from 6 hours for an empty storage facility made of steel to 24 hours or more for an entire food-processing facility. Laboratory and commercial trials with high temperatures during the last decade, especially with forced-air gas heaters and steam heaters, have resulted in a wealth of information on:

1) Understanding responses of insect species and life stages to heat
2) Heat distribution within a treated area
3) Techniques necessary for gauging effectiveness of commercial heat treatments

Electric heaters, forced-air gas heaters or steam heaters can be used to conduct a heat treatment. With the forced-air gas heaters the building is placed under positive pressure during a heat treatment, and the entire air within the building is exchanged four to six times per hour. The number of air exchanges when using electric and steam heaters may be one or two per hour. The forced-air allows heat to reach gaps in the building and equipment much better than electric or steam heaters. The forced-air gas heaters can use natural gas or propane as fuel. Since these heaters have an open flame, they are placed outside a facility, and nylon ducts are placed within the facility to introduce heated air. Hot air has a tendency to stratify horizontally and vertically within a facility. Therefore, several fans should be placed on different floors of a facility to redistribute heat and to uniformly heat a facility.

Fan placement is an art, and during heat treatments fans should be moved to eliminate cool spots, which are areas where the temperature is less than 50°C. In addition to food-processing facilities, heat treatment can also be used in empty storage structures (bins, silos), warehouses, feed mills, and bakeries. It is an environmentally benign and effective method for managing insects.

Heat Treatment of Commodities Versus Structures

Heat has also been used to disinfest perishable and dry, durable food products. High temperature treatments are used for disinfestations of dried fruits, nuts, and perishable commodities such as fruits (Hansen and Sharp, 1998) and grains (Beckett and Morton, 2003). Facility heat treatments are distinctly different from heat treatment of fresh fruits, nuts, or grains. In facility heat treatments, heaters are used to slowly heat the ambient air. A long heat treatment period is necessary for the heat to penetrate wall voids and equipment to kill insects harboring in them. A typical heat treatment may last 24 to 36 hours (Mahroof et al., 2003a; Roesli et al., 2003). In heat treatments of fresh commodities, nuts, dried fruits, or grains, high temperatures of 60 to 85°C are used for short time periods (in minutes). Typical heating rates during heat treatment of perishable commodities, nuts, dried fruits, and grains range from 1 to 15°C per minute, whereas during facility heat treatments, heating rates should generally be around 3 to 5°C per hour for effective disinfestation. However, in both cases the products or facilities are allowed to cool to ambient temperature, and this may take several hours. During heat treatments, it is important to remove all food products and packaging materials (bags) from the facility to prevent insects from seeking refuge in such materials and escape exposure to lethal temperatures.

Equipment should be opened and thoroughly cleaned of any food product where possible. It is important during heat treatments of products to ensure that the quality is not affected. Similarly, in the case of facility heat treatments, it is important to ensure that there is no damage to the equipment. All raw and processed food materials and packaging materials stored within the facility should be moved to a trailer or a suitable place, because during heat treatments insects tend to seek harborage in such materials and escape a heat treatment.

Issues to Consider Before a Heat Treatment

Dosland et al. (2006) gave detailed step-by-step procedures for conducting and evaluating a facility heat treatment. One important aspect of conducting an effective heat treatment involves calculating how much heat energy is required after accounting for heat losses due to exposed surfaces of the facility, equipment, and infiltration (gaps in the facility). Research at Kansas State University and discussions with heat service providers showed that the amount of heat energy should range from 0.074-0.102 kW per cubic meter of the facility per hour, and during a 2009 heat treatment of a pilot flour mill at Kansas State University of 9628 m^3 volume, the heat energy used was as high as 0.16 kW per cubic meter per hour (Brijwani et al., 2012). An indirect method of determining whether or not adequate heat energy is being used is by observing how quickly ambient temperatures reached 50°C. In proper heat treatments, the time required to reach 50°C should usually take about 8-10 hours, and depending on the time of year and the leakiness of a facility, this time can take as long as 15 hours.

The time required to reach 50°C is important to determine the heating rate, which is calculated as the difference between 50°C and the ambient temperature at the start of the heat treatment divided by the time required to reach 50°C. This rate should be between 3 and 5°C per hour in properly conducted heat treatments for effective disinfestation. Temperatures should be held at least for several hours above 50°C to kill insects. The maximum temperature should not exceed 60°C to prevent any damage to structural features of the facility or equipment. Information on temperatures broken down in this fashion can be related to insect mortality if live insects confined in cards or vials are used to gauge the effectiveness of a heat treatment. Research performed at commercial facilities showed that the speed with which insects are killed is related to how quickly temperatures reach 50°C, number of hours temperatures are held above 50°C, and the maximum temperature. The time required to kill 99% of the exposed stages of the red flour beetle were positively related to how quickly temperatures reached 50°C, and negatively related to the number of hours temperatures were held above 50°C and the maximum temperature (Subramanyam et al., 2011). Insect responses to high temperatures vary with the temperature insects are exposed to, among species, and within a species among life stages. For example, in the red flour beetle the young larvae are heat tolerant, in the confused flour beetle and in the cigarette beetle (not usually found in flour mills), the mature larvae and eggs are heat tolerant, respectively.

How do insects succumb to high temperatures? Lethality in insects to high temperatures is dependent on both the temperature and exposure time (Evans and Dermott, 1981; Fields, 1992; Denlinger and Yocum, 1999; Mahroof et al., 2003b). At high temperatures insect cuticular wax becomes compromised allowing loss of water. This affects water balance in insects, leading to death by desiccation as well (Hepburn, 1985). High temperature exposure denatures proteins, affects hemolymph ionic balance and pH, and adversely affects enzyme activity (Denlinger and Yocum, 1999; Neven, 2000). High temperatures that do not kill insects can adversely affect the insect's reproduction (Mahroof et al., 2005).

To gauge heat treatment effectiveness, it is important to identify critical areas in the facility. These areas are usually places where insects can hide and breed or places where temperatures cannot penetrate or reach at least 50°C. Such places are usually identified through inspections. Temperature sensors should be placed in these areas to measure temperatures. Cards with insects such as those marketed by Alteca (http://www.alteca.com) or insects in vials with food (5 g of flour) should be placed in critical areas and examined during or after a heat treatment to determine effectiveness against insects. Insects in the cards compared to insects in vials are usually without food and therefore these stressed or starved insects tend to succumb quickly to a heat treatment and may falsely indicate that the treatment was effective, when in fact it was not.

Traps for crawling or flying insects can be used to determine insect numbers present before and after a facility heat treatment. Trap capture information will show the degree of reduction in captures following a heat treatment when compared to preheat treatment numbers, and how long a heat treatment was effective in keeping insect numbers low. In some facilities such as flour mills, it is possible to sample tailings to determine insect load. These observations should occur every week and should be resumed soon after a heat treatment. The trapping or visual observations of products/tailings following a heat treatment should be done at least on a daily basis for the first week and should continue weekly for at least 8-16 weeks. These data provide valuable information on the degree and duration of control obtained after a heat treatment intervention.

The use of heat treatment for disinfesting facilities is not a new idea. However, research in the last decade and half has shed new light on how to improve heat treatment effectiveness against insects. The susceptibility of many other economically important insect species should be evaluated both at constant elevated temperatures in the laboratory and in commercial facilities subjected to heat treatments where temperatures are changing dynamically over time. There is still scope for lot of research to be done on improving heat treatment effectiveness, especially in commercial facilities. In large commercial facilities, it is difficult to maintain temperatures between 50 and 60°C in all locations. Methods for controlling insects in locations where temperatures are less than 50°C should be explored. The methods may include application of chemical, non-chemical insecticides, and thorough inspection and sanitation. The rate of heating and development of heat tolerance in specific life stages of stored-product insects needs to be explored further. The sub-lethal effects of commercial heat treatments on population rebounds of insects should be verified through carefully designed experiments. The impact of high temperatures or repeated heat treatments on the performance of equipment and on adverse effects to structural components of a facility should be scientifically documented. It is important to recognize that heat treatment may not be suitable for all facilities. However, where it is suitable, heat treatment can be a viable methyl bromide alternative.

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Chapter 4

IPM Application for Processes

Chapter 4: IPM Application for Processes

Section 1: Equipment, Buildings, and Grounds

Note: Much of this section is credited to Kansas State University Research and Extension's publication, Stored Product Protection, Chapter 8: Food plant sanitation, pest exclusion, and facility design, by Jerry W. Heaps.

Scope

Food processors or manufacturers are in a business where what they may not know about sanitation and exclusion of pests, and, therefore, sanitary design may cause them problems. Consumers do not want insects or foreign material in their food. A complete sanitary design treatise can be found in Imholte and Imholte-Tauscher (1999). This current chapter offers basic examples of what to do or not to do, which should increase success in keeping pests out and ensuring that food is safe and wholesome.

Inspection and Monitoring

Plant Exterior

"Know thy neighbor" can be a cliché, but it is important when talking about food plants, warehouses, or storage areas. Stored-product insects (SPI), rodents, and birds do not care where they live as long as they have access to food, water, warmth, and a harborage. Taking away or modifying any of these four critical needs stresses the population. If done well enough, pests will be eliminated or excluded because conditions will not allow them to survive. Elimination, not "control" must be the goal. Consumers have little tolerance of finding live or dead pests in their food. The proper sanitary design of a food plant and its surroundings starts at the plant exterior. Take a tour around the outside of a facility to see what commonly found situations can cause big trouble with pests.

In addition to not allowing critical needs of pests to be satisfied on their property, food processors or manufacturers should conduct a risk assessment of the plant's neighbors on adjoining properties. Pests such as rodents are excellent climbers and are mobile. Insects can easily fly or be windblown onto a property or facility. It is important to assess neighbors' potential as pest harborage sites. The following are some examples of situations that could provide critical need harborages for insects and other pests.

Low Spots

Areas where water accumulates and becomes stagnant not only include such obvious sites as ditches but also any place on a property or adjacent areas where low spots and holes can accumulate water. These will attract insects, birds, and rodents. Whatever can be done to eliminate this type of water source will deter pests. Grounds should be smooth and properly drained.

Trash Areas

Areas where trash, garbage, or litter accumulates should be periodically cleaned to make them less attractive to rodents, flies, and birds. Such sites should be placed on a Master Sanitation Schedule (MSS) for periodic cleaning and inspection. Don't be afraid to approach your neighbors in a friendly manner so that you can work together to keep areas clean. If they also produce food, or receive and store food and its ingredients, you should work as a team to assure that pest attractants are removed. A neighbor's pest problems will ultimately become yours.

Determine where garbage dumpsters or collection area(s) are located on your and your neighbors' property. If collection areas are near plant entry points or dock areas, pests are easily attracted into buildings. Entries must be designed to be pest-proofed. Dumpsters should have tight fitting and accessible lids. These areas should be placed on the MSS for periodic cleaning. Cleaning may require a water source (hot preferably) and a hard, smooth, properly drained surface under containers so no water puddles and stagnates. The interior areas of a cleaned dumpster could also be treated with a labeled residual insecticide to aid in fly control during the summer months. It does no good to treat garbage or a dirty dumpster. Rodent control should also be strengthened near these sites as these sites are obviously attractive.

Landscaping

Trees or landscaping that bear fruit, sweet smelling flowers, nuts or seeds are attractive to insects, birds, and rodents because they provide food and may provide nesting or roosting sites, so they should not be located near a facility. Ideally, landscaping should be designed to minimally attract any of the above (Beach, 2012). Many facilities realize this too late and end up removing plant material around perimeters and foundations of buildings. Even low-growing shrubs like arborvitae should not be planted near the foundation because this becomes a hiding location for rodents and other vertebrates. Flowering shrubs like Spirea attract adult warehouse beetles (Family: Dermestidae) to feed on the pollen in the flowers. If these are located near the building, they will attract the adults. If these adults are not prevented from flying into the facility, eggs may be laid in many grain-based food products where their larvae feed, starting an infestation.

Parking Lots and Lighting

Parking lots, adjacent properties and similar sites should be paved and constructed so water drains properly and does not accumulate. The goal is to eliminate standing water.

Lot lighting should be designed so as not to attract night-flying insects. This means sodium vapor lights are a better choice than mercury vapor. Wherever possible, facilities should use sodium vapor lighting for exterior and for interior areas where light may be visible from outside. These lights, which are known for their orange or gold color, emit low levels of ultraviolet light which is attractive to insects. Another advantage of this type of lighting is that the bulbs have a low mercury content making them more environmentally friendly than mercury vapor lights.

Ideally, lighting should not be placed directly on building exteriors or above personnel or dock doors. For security lighting, lights should be placed at least 15 feet from the doorway so that they illuminate, but attract insects away from the building. This will help ensure that the areas are well lit while minimizing insect congregation at the entrances. If entrance lighting on a building is needed, sodium vapor or metal halide lights should be specified because ultraviolet emissions are low. Photocell sensors can be placed on the lighting so that they only turn on as needed.

There is a trick to using insect-attracting mercury vapor lights to your advantage by luring flying insects away from the facility. Such lighting can be placed away from the building and shrouded to project the light down, minimizing attraction of insects from surrounding areas to ultraviolet emissions. (Harris, 2006)

Sanitation Controls

Focus on sanitation in plant equipment, buildings, and grounds is most easily made by breaking the tasks down into two areas: the plant exterior and the plant interior. Sanitation frequency should be based on inspection results and a risk assessment.

Physical Controls

Other Key Sanitary Design Issues for Plant Perimeters and Building Exterior

Walls, roof, and foundation areas must be constructed to remain dry with no water accumulation or entry allowed for reasons discussed previously. Water is a critical need for warm blooded, insects and microbiological pests which can cause *Salmonella*, *Listeria* and *Escherichia coli.* Just consider what these bacteria have done to the food industry.

Even the color of the building can increase insect attraction. The colors white and yellow are more attractive as a result of their reflective qualities. If possible, minimize the use of these colors on exterior and in critical interior areas, too. If present, minimize the amount of light shining on these surfaces and reflected from them.

A vegetation-free perimeter around buildings is a must. An 18-inch band of pea gravel is recommended as this diameter of stone makes it difficult for rodents to burrow into it for nesting. Gravel that is not pea-sized does not collapse back on itself when moved and may not deter burrowing. Rodent bait stations are placed along this perimeter, either with or without toxic bait, in response to rodent activity observed during good manufacturing practices (GMP) inspections. Many facilities now only place glue boards inside bait stations. Glue boards must be protected from the weather and debris and inspected frequently enough that catches are removed before decomposition and before the glue boards can be replaced. All activity should be noted in a log. Third party inspectors cannot find decomposed rodents in any trap. That would likely trigger an automatic "unsatisfactory" rating due to neglect or lack of disciplined checks.

If grass is allowed to grow too long and pallets are stored outside next to the foundation, pests will find shelter and may create issues. A pallet inspection and cleaning program is necessary before moving any pallets stored outside indoors. Birds and rodents can sometimes be found nesting in these pallets. Droppings are of equal concern as a pallet contamination issue.

A few common stored-product insects that can feed on mold/fungi found on wet pallets, inside or out, include psocids or book lice (Family: Psocidae), rusty and flat grain beetles, foreign grain beetles, and hairy fungus beetles. Wood pallets are a threat to sanitation and good management practices. The wood can splinter and cause foreign material contamination in production areas (Figure 1). Pallets should be inspected for pest evidence not only near the floor, but also several feet high in a stack. Rodent droppings can sometimes be seen on pallet boards several feet up in a stack that ends along warehouse walls. If using pallets, implement a documented cleaning program. This may be even more important if pallets are stored outside and moved inside.

Roof areas should be part of the monthly good management practices inspection route. These inspections are done by a multidisciplinary team where deficiencies observed are noted for proper corrective action and determination of cause. It is important to act promptly to resolve issues. A similar observation noted repeatedly indicates a program break down. Immediate identification of the root cause is needed so it can be addressed to prevent a reoccurrence.

HVAC (heating/ventilation/air conditioning) units and venting should be checked for proper function with no leaks. Leaks can deposit food debris on the roof that will attract pests of all kinds. Roofs should be constructed of an easy to clean and smooth surface and be drained properly to prevent accumulation of water that can stagnate and lead to problems. Roofs with a gravel base are very difficult to clean and remove debris. All HVAC utilities should be properly screened or filtered to keep pests out. Personal safety is the priority when working on the roof. Regulatory inspectors are now making the roof area a primary focus of inspections. They have often been neglected because they are out of sight. Roof access points from inside the plant should be secured and monitored so personnel do not use them as “break” areas, leaving behind food and debris. This is unacceptable from a GMP standpoint.

Entrance, exit, rail, or dock doors should not open directly into plant manufacturing areas. Open doors allow pests and unfiltered air into the plant. Positive air pressure rather than negative air pressure is needed inside the plant to prevent pests from being sucked in. Doors can be screened during warmer months when ventilation is needed. Emergency exit doors that open directly to the outside should have security alarms. Doors should be tightly sealed along the bottom so rodents cannot enter. Air curtains above doors are not recommended because, more often than not, they malfunction and do not adequately keep pests out. Plastic strip doors are seldom a good option. They deteriorate and need constant repair to keep pests from getting in, adding to maintenance and upkeep costs (Fig. 2).

Docks and Warehouses

Insect and other pest infestations often originate in warehouse areas because that is where food ingredients and finished food products are stored. They are also located by receiving and shipping dock doors. This is a critical area for pest control. Maximize rodent control by using non-toxic traps (*i.e.*, snap, mechanical multiple catch, glue boards) on either side of each door that opens to the outside. Place rodent bait stations outside along the building perimeter. Doors and windows should not be left open and unattended. They should be properly screened when ventilation is needed. Food spilled around exterior docks should be promptly removed so as not to attract pests. Insect light traps and pheromone traps (Mueller and Van Ryckeghem 2006) can be strategically placed around dock and warehouse perimeters to catch flying insects. These are not a panacea because not all insects are highly attracted to them.

Dock levelers must be fitted for pest prevention/exclusion. Rodents can easily crawl into the plant through the leveler pit when the plate is not sealed. Plates are usually equipped with brush seals or pieces of heavy rubber. Rodent mechanical multi-catch traps can be placed inside the leveler pit as part of the rodent control program. Pit areas should be placed on the Master Sanitation Schedule for periodic cleaning and should be part of the GMP inspection program.

Exterior food ingredient commodity storage tanks should be constructed of food- grade materials that will withstand the rigors of the outside environment and not rust. Tanks should be smooth and cleanable, inside and out, for easy maintenance (*i.e.*, preferably not painted because peeling paint can become a product contaminant). Dust collection units or other HVAC ductwork must be screened or filtered to prevent pest entry. They should be watertight and non-leaking. Be sure such sites are placed on the MSS and the preventative maintenance program to document upkeep. Welded joints should be continuous and not stitched. Stitching creates cracks and crevices where food debris accumulates and stored-product insects such as red or confused flour beetles or sawtoothed grain beetles can live. Indian meal moths are a type of stored-product insect that will infest interior tank headspaces and HVAC units if given the opportunity. Check these sites periodically for pests. If applicable, check sifter tailings coming out of the bins to detect pests and foreign material. Do not log these problems without finding the cause.

Moisture supports mold or fungi inside a dry ingredient storage tank. Precautions to prevent condensation and leaks should be designed into the system. Condensation can occur when warm ingredients are unloaded into a cold silo during cold months. This can become a problem without adequate ventilation.

External Ingredient Unloading Sites

External food ingredient or commodity unloading sites must be designed to exclude stored product insects such as red or confused flour beetles, sawtoothed grain beetles, foreign grain beetles, flat or rusty grain beetles, hairy fungus beetles, psocids, ants, flies and bees, or wasps. Other arthropods such as sowbugs and millipedes will also be attracted to moist food debris when it is allowed to accumulate around the unloading site. Rail siding or lots where unloading occurs should be paved and drain properly. They should be able to be cleaned without using water because moist debris will decay and attract pests. When rail unloading areas are covered with gravel or rock, cleaning up spillage is nearly impossible. Debris that sifts down through the gravel or rock attracts pests by satisfying their critical needs. Treating the track area with insecticides does not eliminate the underlying cause.

If exterior storage tanks or silos are covered with a protective head house, pest control and sanitation programs in these areas must be thorough. Insect pheromone traps can be hung for Indian meal moths, drugstore/cigarette beetles, and warehouse beetles. They are species specific and effective for monitoring flying stored product insects. Trap locations should be marked on a schematic map. They should be checked weekly and catches for each trap recorded in a log. Typically, head houses are not heated or airtight enough to be sealed easily from the inside and properly fumigated with labeled products. Inadequate fumigation increases the likelihood of insect resistance. Resistance is already occurring in some cases.

If the head house can be sealed to hold in hot air, heat can be used for insect control. The temperature should be maintained at 122^{o}-125^{o}F for 18 to 24 hours, giving the heat enough time to penetrate the cracks and crevices. Heat treatments stress insect populations and help limit reproduction. Windows are discouraged. Left open or unscreened, they allow pests to enter. Broken windows lead to product contamination. Top hatch openings to tanks or silos should be secured to keep foreign material from getting into the tank. Insects adapt and can survive during the cold months even outside in a head house. They will not reproduce below 50º-55ºF, but they will survive.

Food debris spilled during unloading should be promptly removed. Unloading hoses should be clean, capped, and locked when not in use and stored off the ground in a sanitary location. Ideally product protection devices such as magnets, sifters, filters, or strainers for products being unloaded should be installed before products enter the storage bin or silo. This prevents suppliers from unloading their problem into the bin. Devices should be inspected after each load and observations logged. If contaminants are observed, act immediately to assure no product becomes adulterated.

Plant Interior

Considerations inside the plant are also of great importance.

Floors

Warehouse floors should be designed for equipment and usage. What will be the equipment and human traffic patterns? Will equipment be heavy? Will water or cleaning chemicals be used? Answers to these questions will determine what type of flooring will perform best and last the longest.

Wood floors are not usually a good choice. Many older facilities have them and must maintain them in order to prevent cracks and crevices that allow food debris to accumulate and insects to breed. Wood floors are high maintenance and must be kept sealed with several coats of a polyurethane sealer. Concrete floors are common, but joints need to be sealed, and floor sealers do not last indefinitely. Highly acidic foods damage concrete floors, allowing food and water to accumulate, stagnate, and cause insect and microbiological issues. Phorid flies (Phoridae), moth flies (Psychodidae), dung flies (Sphaeroceridae), and fruit flies (Drosophila spp.) are among many flies that are attracted to breed in stagnant water. They will even breed under loose sections of flooring that come up and are not properly sealed. If the floors are not properly repaired, the flies will remain, and insecticide treatment is futile. Because of how they are constructed, tile floors are often a poor choice for flooring. Their seams tend to come apart or split over time, which allows food debris and water to accumulate. Water stagnates and leads to serious insect and microbiological issues.

Physical Controls

Ceilings

Ceilings and overheads should be periodically inspected for pest evidence and cleaned. Do not overlook overhead areas as potential runways for rodents. They are excellent climbers. Condensate should not be allowed to accumulate in overhead areas because it becomes a source of moisture for pests. HVAC should be designed to remove any condensation. False ceilings should be avoided if possible. Stored-product insects and rodents can be found in false ceilings where flour and food debris accumulate. If personnel forget to clean and inspect false ceilings, pests can take over. Fogging is ineffective if these areas are dirty. If used, false ceiling areas must be placed on the MSS. Implement a pest control program (*i.e.*, monitoring rodent and insect traps) for false ceilings.

Wall Openings

All wall openings (*i.e.*, for pipes, wiring, etc.) must be sealed to keep pests out. Caulking and copper wool works best. Copper wool does not rust like steel wool and will prevent rodent chewing better than caulk.

Floor Drains

Floor drains can pose problems for the plant sanitarian. In dry environments, if food debris/flour is allowed to accumulate, stored-product insects will take harborage in the drain. In a wet environment, microbial concerns abound. In dry warehouses or production areas, drains can be cleaned and then plugged when not in use to ensure they stay clean and infestation free. Drains should not be allowed to dry out. Place drains on a schematic map and document when they are cleaned on a MSS. Unplug drains while doing a heat-up in case a sprinkler head or two discharge. This keeps personnel from having to enter a hot room and unplug the drain while the sprinkler is going. Ideally, floor drains should be a minimum of four inches in size and equipped with a removable secondary strainer to prevent cockroaches, rodents and other pests from entering the facility through the drain pipes. Plus, the strainer prevents large accumulations of organic material from entering the drain and causing a backup. Drains should be constructed with smooth surfaces and rounded corners.

Trench drains are difficult to maintain in a sanitary manner. They should be used in operations where required by the food being manufactured. Trench drains may deteriorate, causing the floor drain interface to separate. This allows water and food debris to get into the cracks and stagnate. Many fly species will breed here and can only be eliminated by repairing the separation.

A floor drain should be closely monitored for pests, and adequately cleaned and sanitized. It is important to have written drain cleaning programs and procedures that require physical scrubbing of the drain sides and piping into the drain. This is the only way to remove biofilms that accumulate in wet drains. Simply pouring cleaning or sanitizing solutions into a drain will NOT remove the biofilms. Insects will live under them and continue to breed. Utensils used for drain cleaning should be designated as such, using color code and labeling and ONLY used for this purpose. Using drain-cleaning utensils to clean food contact surfaces will cause cross-contamination and is a violation of GMPs. To verify that drains are a source of an insect pest, place a plastic bag over the drain and tape it to the floor for 24 hours. Check the bag for insects. Re-clean, scrub, and sanitize the drain.

High-pressure water or air should not be used in drains or anywhere else such as overheads. This only scatters debris and contaminants (*i.e.,* microbial and insects) into the general manufacturing environment, causing cross-contamination. Vacuuming is the preferred method after removing large debris. Using a squeegee to corral large amounts of debris in a wet environment is preferable to using high-pressure water.

Electrical Equipment

Electrical equipment and systems are extremely vulnerable to stored-product insects, especially sawtoothed grain beetles and confused or red flour beetles. If such equipment is poorly designed so it does not remain dust- and water-free, it will become a pest harborage. Thousands of feet of conduit will become insect-breeding expressways. Even overhead light fixtures can become infested. They are warm, and ultraviolet light attracts several insect species. Pesticides are not recommended for use in such areas. Heat can be used to disinfest areas, but only if systems are designed to withstand the high temperatures. Overcompensate with temperature specifications because “hot spots” can occur during a heat up. Installations must meet appropriate code requirements, too.

Switch gear and control centers should be installed in well-lit, pressurized rooms. They should be filled with filtered and air conditioned air and able to be cleaned easily without high-pressure air. No small voids should be allowed between equipment and wall, or wall and floor interfaces. Dust can accumulate and breed stored product insects. Installations should allow adequate inspection space under and around equipment. There should be no hollow voids for materials to enter and accumulate.

Control panels installed in manufacturing areas also should be dust- and water-tight. Panels can be pressurized with clean, filtered air. Supporting leg bases should be designed so there are no hollow voids that could allow debris to enter from the sides or where they attach to the floor. Be cautious if using caulk as a sealant. It can become loose, creating a harborage. It cannot be applied and forgotten. When caulking is used, inspect it periodically to ensure it is intact.

Motor and Equipment Leg Bases

Motor and equipment leg bases often are overlooked during cleaning. There are numerous cracks and crevices and ledges in motors where debris accumulates. They are warm, which favors breeding of stored-product insects. Clean motors at least monthly and include them on monthly GMP inspection routes.

Equipment leg bases that sit firmly on floors also accumulate debris that can create a harborage for insects if they are not sealed directly to the floor. Sites are sometimes painted over and over again so that crusty paint looks like it belongs there and is part of the equipment. Once loosened and scraped away, flour beetles or sawtoothed grain beetles can be found living there.

Windows

Making sure windows and doors are kept closed, tightly sealed to exclude moisture and properly screened in a food plant or warehouse can be a struggle, especially during “off” shifts. Because of the many problems they cause, it is a good idea not to have windows in the first place. Insects cannot fly into the plant if windows are excluded. Even with the most advanced HVAC units, someone gets too hot and feels the need to open a window. Open windows require screens that themselves become maintenance issues with expense.

If windows or glass block windows that let light in but cannot be opened are used, do not allow the use of any type of glass in or near production of food or packaging due to the potential for breakage and contamination.

Window screens used for exclusion should be constructed of 16 mesh with 14 x 12 wires per inch. Screens should be designed for easy removal and cleaning. Screens within 5 feet of ground level should be reinforced with a heavy-gauge wire and ¼- inch mesh screen for rodent-proofing because rodents can chew through conventional screening. Any screen hole should be promptly repaired for maximum pest exclusion.

Windows can be tinted to reduce the amount of insect-attracting light shown through them. When inspecting the plant, a tip is to look for dead or alive insects that have been attracted to the sill areas. Identify them so you know where their source is, react to what you find, and eliminate the source.

Fig. 1. Damaged corner of pallet is a GMP concern

Fig. 2. Damaged bottom of plastic strip doors allows pest entry

Chemical Controls

Pest Control Programs Around Perimeters

A pest control program should start at the property perimeters, especially for rodents. This typically involves using EPA-labeled toxic rodenticides placed securely inside commercially available tamper-resistant rodent bait stations (RBS) secured to the ground. Baits should be of a solid formulation in most cases. This prevents rodents or other non-target organisms from removing them from the bait stations and moving them to another site where non-target organisms may be killed or injured. This is not desirable because not only is it against the law, but it also generates bad press for the guilty party. The rodent bait station locations should be marked on a schematic location map for periodic (*i.e.,* biweekly at least and more often if rodent pressure is heavy) inspection and maintenance by trained personnel. Observations must be documented in a log. Move bait stations as rodent activity decreases.

Do not be lulled into rodent control, inside or outside of the facility by guidelines of auditing companies that say control devices need to be placed "x" number of feet apart. Rodents may only move a few feet from their nests when food and water are easily available. They tend not to move in the open where they are exposed to potential predators. Experiment with different bait varieties as well to find the best one for the situation. It is recommended that you "disturb" the rodent bait station before inspecting it because snakes and other vertebrates may be found there. Check for black widow spiders, if present, in the area as well. Rodent bait stations should not be placed in low spots where they get wet or covered with water and become ineffective. During winter, it may not be possible to inspect the stations. They should be well stocked with bait and well maintained before the onset of bad weather.

It is not necessary to use toxic baits inside the bait station all the time. Nontoxic rodent attractant blocks are available that can be used as a monitoring tool to indicate rodent feeding. Once such activity is noted, replace the nontoxic material with the toxic bait. Keep doing this until the feeding activity stops. Repeat the process as needed. This regime greatly limits the amount of toxicants used and the associated liability with regard to non-target organisms.

Another nontoxic method of rodent control along perimeters is placing glue boards inside rodent bait stations. The caution here is that glue boards become ineffective if they get wet or dirty and may be difficult to maintain. These traps catch insects and other small invertebrates or vertebrates that should be monitored. A combination of these methods might work best in a particular situation. Be creative as long as it is legal and works. Snap traps are not typically used outside because after they are "tripped," they are ineffective, which makes them high maintenance because they must be checked frequently.

Overheads should be placed on the MSS. Fogging with synergized pyrethrins or other labeled insecticides will not be effective on dirty overheads because the insects live underneath built-up debris where they are protected from insecticide. Fogging is most effective if the droplets hit the exposed insects.

Summary

As you can see, checking sanitation problem areas in the plant buildings, equipment, and grounds is a hefty task. Those responsible for these areas should study this section closely to help build an effective Master Sanitation Schedule and GMP inspection program.

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Chapter 4: IPM Application for Processes
Section 2: Grain Receiving and Storage

Introduction
This chapter will describe integrated pest management (IPM) strategies, including chemical control, for grain receiving and storage as applicable to conditions in the United States. General discussions will be provided for specific topics, but more complete information can be obtained from several recent publications, including Stored Product Protection, published by Kansas State University in 2012. This book gives extensive coverage of the topics that will be listed below. In addition, information can be obtained from university websites, private companies specializing in insect pest management in bulk grains, and scientists with the USDA-ARS-Stored Product Insects and Engineering Research Unit in Manhattan, Kansas.

This text is meant to provide general information and list references where readers can access more complete information. This chapter will focus on bulk stored grain in bins and silos. Individual storage units can range from farm silos containing 500 bushels to large grain elevators containing multiple concrete silos with as much as 100,000 bushels in just one individual silo. Hence, this chapter will just describe management strategies in a general manner, as variation in the size and complexity of different storage facilities requires approaches that may be specific to a given situation.

Pre-binning Treatments and Approaches
Regardless of the size of the bin, sanitation and cleaning are important components of management programs. Residual grain in the bottom of a bin, spillage in and around the facility, and old grain piles are sources of infestation for new grains being brought into the facility. Empty bins can be fumigated with phosphine or treated with a residual insecticide. One current product that can be used as residual treatments is Storicide II®, which is a mixture of the organophosphate chlorpyrifos-methyl and the pyrethroid deltamethrin; however, this insecticide can only be used as a pre-binning treatment if you are storing one of the five commodities for which it is labeled: barley, oats, sorghum, rice, and wheat. The pyrethroid cyfluthrin (Tempo® SC Ultra) can be used as a pre-binning spray, but it is not labeled for direct application to stored grains. The insecticide deltamethrin (either Centynal® or Suspend®) can be used as a pre-binning treatment. Methoprene (Diacon IGR) can also be used as a pre-binning treatment. Diatomaceous Earth (DE) is a natural product composed of the fossilized shell walls of diatoms, and there are a number of formulations labeled for use as a pre-binning treatment. Insecticide labels must always be consulted for specific directions and requirements regarding usage, label rates, and specifics regarding the application process.

Grain Protectants
Grain protectants are contact insecticides that can be applied directly on grains as they are loaded into storage. There are a variety of commercial products, but not all protectants can be used on all commodities. Storicide II® can only be applied to barley, oats, sorghum, rice, and wheat. The organophosphate pirimiphos-methyl (Actellic®) is registered for corn and sorghum only. Centynal® can be used on different commodities in accordance with the label listings. The insect growth regulator methoprene (Diacon IGR®) can also be used on multiple commodities, but this

insecticide does not kill adults, instead it limits molting and development of immature stages or adults capable of reproduction. As mentioned previously, there are several different commercial formulations of DE that can be applied directly to bulk grains. Not all formulations of DE are used at the same rates, and the rates can differ with grain commodity or oilseed crop.

Specific application rates of these different insecticides for the various commodities are listed on the product labels. These labels are legal documents that must be followed during insecticidal applications. Labels can change as directed by the U.S. Environmental Protection Agency but the label "in hand" should be followed. It is a good practice to frequently contact your pesticide supplier to be sure no label changes have occurred. Insect species vary in their susceptibility to insecticides, and insecticidal efficacy of specific insecticides can vary with commodity. Various factors affecting efficacy of these registered insecticides are discussed in a number of recent publications listed at the conclusion of this section.

Several insecticides are not widely used today for grain management but may be available for use in specific situations. Malathion was once a common grain protectant, but problems with insecticide resistance, availability, and regulatory restrictions have curtailed usage, though some use still continues today. Commercial formulations of synergised pyrethrins are available, and usage is relatively low but may be increasing in organic storage. One new product that may be available in the near future is the biological pesticide spinosad, which is not currently being sold in the U.S. due to marketing restrictions. However, this may change in the next few years. There have been more than two dozen research papers on spinosad published in the last 15 years; selected references are listed.

Aeration

Aeration is considered to be the practice of using low-volume ambient air to cool a grain mass, and thereby lower temperatures to levels that will restrict insect development. It is not to be confused with drying, which uses higher airflow rates to remove moisture from grain prior to storage. Airflow rates used in aeration typically are in the range of 0.05 to 1 cubic feet per minute (cfm) per bushel, while rates used in drying are typically in the range of 1 to 5 cfm per bushel. Drying can also involve the use of forced heated air. A common management strategy is to cool grains below 60°F, which is the approximate limit of development of most stored product insects. However, for summer storage of wheat and for warmer regions of the southern U.S., an initial cooling down to the mid-70s°F may be advantageous. Similarly, recent research is indicating that suction aeration, pulling air downward through the grain mass, will cool the top of that grain mass more quickly than pressure aeration, pushing air upward through the grain mass. A more complete description of aeration can be found in Chapter 11 of Stored Product Protection.

Insect Monitoring

There has been considerable research on monitoring insects in stored grain, either through direct sampling of the grain mass, or indirect sampling using probe or pitfall traps. Direct sampling can be time consuming, and depending on the size of the bin or facility, may or may not be practical due to the labor costs involved. Indirect sampling through probe traps will provide information, but multiple factors including temperature, specific insect species and their habits, trapping intervals, and density of traps will influence the actual number of insects or species caught in a trap. Time and labor costs are also involved with trapping. Nevertheless, monitoring programs will provide information regarding effectiveness of insecticide applications, seasonal patterns of infestation and can also aid with the timing of fumigation treatments. A comprehensive discussion of monitoring can be found in Chapters 18 and 21 of the Stored Product Protection and other references listed at the conclusion of this chapter.

Fumigation
Fumigation with phosphine remains one of the most important management strategies to control insects in bulk grains, especially in large commercial elevators with multiple silos. There are a variety of options for application of this fumigant, but it must be done only by persons licensed to apply the fumigant. Legal restrictions must be followed, including the development of a fumigation management plan, monitoring gas concentrations during fumigation, and venting of the gas after the fumigation is complete. In addition, some companies are specifying that fumigations must be done from outside of the grain bin or silo, and direct entry of personnel into the structure is not being allowed. A complete and thorough discussion of fumigation is given in Chapter 14 of Stored Product Protection.

Summary

In this chapter, several of the major components of an IPM program have been discussed for grain receiving and storage. The recent KSU publication has been cited as a primary source of information, because it gives a comprehensive discussion of these major components. Recent references are also provided but this is not an exhaustive or complete list, and many publications from scientists with the USDA and state universities can be accessed through their respective websites.

Acknowledgements

Information reported in this chapter is for educational purposes only. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture (USDA) or the International Association of Operative Millers. The USDA is an equal opportunity provider and employer.

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Chapter 4: IPM Application for Processes
Section 3: The Cleaning House and Tempering

The primary purpose of the cleaning house is to physically remove foreign material, other grains, damaged kernels and insects. If the wheat has not been pre-cleaned prior to storage in the elevator, this is the first chance to remove contaminants from the grain. Some of the equipment that may be used in a cleaning house to remove contaminants could include separators, scourers, aspirators, bran peelers, and infestation destroyers. After the wheat is cleaned of foreign material, it is prepared for milling during the tempering stage where water is added to toughen the bran coat. This stage of the milling process creates a preferred environment for microbes. Chlorine is sometimes added at this stage to keep the microbial load to a minimum.

Inspection and Monitoring

There are many areas in the Cleaning House that can lead to potential problems due to harborage areas. These areas need to be identified and must be inspected frequently and cleaned out as necessary.

Here are some of the common areas in the cleaning house that need periodic inspections for insect activity.

- All working and blending bins need to be emptied on a routine basis so they can be inspected and cleaned as necessary.
    - This includes visually checking the interior bin condition including its floor and walls, and checking the roof of the bin from the outside.
    - The bin bottoms need to be cleaned and swept on a routine basis.
- Bucket elevator boots need to be inspected on a routine frequency and cleaned as necessary.
- All conveyors need to be inspected and cleaned as needed
- Spout dead boxes should be self-cleaning, but must be inspected
- Aspiration lines should be inspected for excess material and insect growth.
- All cleaning equipment should be internally inspected to identify areas of product build up and insect activity.
- The overs and "thrus" of cleaning house equipment should be inspected to make sure that equipment is set up properly in removing contaminants. It is important to have proper control of the removed material to prevent insect infestation in the plant.
- All tempering equipment and temper bins shall be inspected and cleaned on a routine frequency. The wet grain and humidity create ideal conditions for product build-up, mold and insect growth.
    - Typically the wheat movement will scour clean the internal bin bottoms and walls, but they need to be inspected for any hung up material
    - Detailed inspections of the head space, ceiling and upper corners is important as these areas are not scoured clean by the grain.
    - The tempering conveyors and distribution conveyers must be inspected and cleaned regularly.
- Temper elevator boots should be inspected and cleaned as needed

- All spouts should be inspected periodically

Sanitation
All of the areas inspected above should be cleaned on a periodic basis. This frequency will depend on the inspection findings and should be adjusted as needed.

Housekeeping in the cleaning house should be performed on a daily basis. Spills and piles should be cleaned up and fed in or disposed of as soon as possible. Consult local policy for details of disposition.

Chemical Controls
If the need arises, chemical controls in a cleaning house could include crack and crevice applications with an Insect Growth Regulator (IGR); spot fumigation; and fogging (including an IGR) of nonfood contact areas. The cleaning house is typically part of any plant wide fumigation treatment.

Chlorine or ozone may be added to the temper water to reduce the microbial load.

Physical Controls
The Cleaning House equipment's primary purpose is to physically remove foreign material, other grains, damaged kernels and insects from the grain prior to milling.

Other Controls
Heat treatments as described in Section 3.5 may also be used in the mill.

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Section 4: Mill Operations

Once the wheat has been tempered for the proper amount of time, it enters the actual milling process where it becomes flour. Effective inspection and cleaning schedules must be followed and documented in this area as well. Redressers need to be serviced on a routine frequency to make sure all screens are intact. There must be routine mill cleaning of overhead areas with vacuums and low pressure air when the mill is not operating to eliminate build-up on beams, spouts, ledges, corners, and junctures. Cleaning in the mill incorporates dry-cleaning procedures such as additional vacuuming, brushing, or scraping. The use of high pressure air for "blowing down" is not recommended as this only moves debris, and possible insect life stages, to other areas where it may accumulate, causing sanitation/pest issues.

Inspection and Monitoring

Areas for inspection on a frequent basis include:

- Examining mill sifter tailings for insects
- Looking for insect trails
- Making sure all windows and door screens are intact
- Making sure all doors are shut and sealed properly.

Areas for inspection on periodic basis:

- Look for insect harborage on feeder rolls and hoppers of rollstands (including the roll brushes).
- Inspect purifier channels and feeder gates on a routine basis and clean as necessary.
- Drop bucket elevator boots and clean periodically to avoid insect contamination.
- Inspect frequently the aspiration ducts throughout the mill.
- Inspect the knees, socks, and hems of sifters as there are many areas where insects can hide.
- Eliminate dead channels in sifters and dead spouts in the mill where possible and inspect and clean those that cannot be eliminated since flour can leak into them.
- Check stream splitters as these are another area where insects can thrive if left unattended.
- Inspect agitators often and clean as necessary to avoid insect contamination.
- Inspect both choke feed in areas and set-off bins as these are critical areas for insect harborages.
- Inspect temporary repairs frequently for evidence of insect activity until permanent repairs are completed.

Sanitation

All of the areas inspected above should be deep cleaned on a periodic basis. This frequency will depend on the inspection findings and should be adjusted as needed.

Housekeeping should be performed on a daily basis. Spills and piles should be cleaned up and fed in or disposed of as soon as possible. Consult local policy for details of disposition.

Physical Controls
Mills typically have a flour redress sifter between the mill and bulk storage. This is primarily for process and quality control but they are capable of removing insects from the product. In most cases though, the tailings of this sifter is spouted back into the mill.

An infestation destroyer after the mill before bulk storage is another best practice.

Chemical Controls
Pest Control in the mill may include crack and crevice applications, which include an Insect Growth Regulator (IGR) and also fogging with an IGR. Be sure to follow the label for application rates and method of use.

Certain fumigants listed in Section 3.4 may be used in the mill as part of a plant wide or a spot fumigation.

Other Controls
Heat treatments as described in Sect 3.5 may also be used in the mill.

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Section 5: Bulk Storage

After the flour is milled, it is stored in large bulk bins. It is important to inspect these bins on a scheduled frequency and to clean them as necessary. Some particular areas to consider include:

- Put all bins on a pre-determined schedule to go empty so that they can be thoroughly inspected and cleaned.
- Use dry cleaning primarily on bins using brooms, brushes, vacuums, and scrapers designated for product contact surfaces.
- Inspect and clean bin tops as necessary.
- Document all inspections and cleaning.

The potentially critical areas in bulk storage are the bin bottoms. Blend vein feeders or vibratory bin dischargers need to be inspected on a routine basis. Also, inspect all aspiration ducts. The steel bin flanges may also be an area where flour accumulates and becomes a harborage for insects.

Pest Control in the bulk storage area may include crack and crevice applications that include an Insect Growth Regulator (IGR), fogging with an IGR, and spot fumigations of specific bins. Be sure to follow the label for application rates and method of use. See Chapter 3 section 4 for more detailed information regarding the specific insecticides and other management strategies that can be used in various components of bulk storage. Mechanical mouse traps in the can be used as monitoring tools to detect the presence of rodents in and around the bulk storage.

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Section 6: Transfer and Load-Out

Transfer and Load-Out Bins

Prior to shipping to the customer, the flour is transferred from the bulk mill bins to load-out bins. Many of the same concerns that exist for the mill bins also exist here.

- Examine sifter tailings frequently to make sure that there is nothing that could have been detrimental to the sieves.
- Disassemble sifters on a routine basis to assure the integrity of the sieves.
- Check the air pads on the load-out bins.
- Drop the bottoms on pick-up conveyors periodically to clean out any flour that may remain there.

Removal of Contaminants

Sifters and infestation destroyers or pin detachers are specifically used to remove contaminants during the transfer and load-out of the flour (Subramanyam Bh, Impact Machines: A Look Back and Impact Machines: Experiments). Other areas potentially critical for insect contamination and inspection include:

- Access and clean leg boots, if present, on a specified routine basis.
- Clean aspiration ducts frequently and ensure that the dust returns prior to the sifter and infestation destroyer.
- Inspect sifter socks and load-out socks and replace as needed.
- Inspect and clean as necessary the dust control loading spouts in the bulk scales area where flour dust can accumulate and create an insect harborage.
- Employ thorough, routine cleaning practices in areas in the load-out shed where insects can thrive.
- Avoid dead load-out spouts, where possible, and make sure all hoses are capped when not in use.
- Ensure there is no build-up in the corners or on the paddles of any bulk mixers you may have.
- Ensure that filter boxes on PD blowers are operating properly and not blowing in dust and/or insect fragments from the surrounding environment.

Pest control in the transfer and bulk load-out area may involve spot fumigation of specific bins. Follow the label directions for proper use.

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Section 7: Packing and Warehouse Sanitation

Packing and warehouse sanitation activities will center heavily on the type of products you keep in inventory. Certain products are susceptible to stored product pests and require special handling. We will assume that this is the case in the following.

Good Warehousing Practices

Good warehousing practices can be broken up into several categories such as the following:

Doors and Windows

- Have tight seals on all doors and keep them closed when not in use, including both pedestrian and roll-up.
- Properly screen windows or close them if screening is not adequate.
- Avoid interior lights where visible from the outside - through doors or windows. Be sure insect light traps are not visible from the outside through doorways or windows - as they will attract insects.

Receiving

- Ensure that all incoming materials arrive in a locked or sealed trailer.
- Inspect all incoming material for damage and evidence of pest activity.
- Inspect all incoming trailers for possible pest harborage and odors.
- In the case of Less-Than-Full Truck Load (LTL) shipments, check for products not allowed to ship with food.

Warehouse Interior

- Ensure that product storage areas have an accessible, 18-inch perimeter along the warehouse wall to allow for proper cleaning and inspection.
- Keep all doors closed when not in use, including both pedestrian and roll-up.
- If insect screens are used, ensure they are adequate to protect against pest entry.
- Maintain dock plate brushes to prevent pest entry.
- Seal floor/wall junctions and ceiling/wall junctions to prevent pest entry and harborage.
- Seal around all equipment legs to prevent pest harborage.
- Maintain floors so as to avoid cracks or pits, as these allow product accumulation and pest harborage.
- Clean structural overhead and support beams on a frequency that will prevent pest harborage.
- Repair cracked or pitted floors to prevent product accumulations and pest harborage.

- Clean structural overhead and support beams on a frequency to prevent pest harborage.
- Set cleaning frequencies to avoid product accumulations. This frequency will depend on your operating environment.
- Avoid placing insect light traps in close proximity to doorways.
- If air curtains are in use, include them on the Preventative Maintenance schedules.
- Ensure interior, multi-catch rodent trapping is present and adequately spaced for effective control of pest pressure.
- Stored-product insect pheromone trapping program should be used to monitor for stored product insect activity.

Stored Product and Ingredients

- Monitor inventory on a regular basis to ensure proper condition of aged product. This will include finished product as well as micro ingredients and packaging materials.
- Establish acceptable timelines for product storage.
- Adjust production schedules to control lengthy floor times for finished products.
- Inspect products housed over 30 days for condition and address according to inspection findings.
- Ensure FIFO (First In - First Out) rotation of products and ingredients that are stored in the warehouse.

Packing Equipment

- Having complete knowledge of your equipment is crucial to preventing product accumulations in areas where harborage can occur. Consider the entire piece of equipment, bag magazines, packer sweeps, filling tubes, hoppers, scales, posser cabinets.
- Brushing down and then vacuuming is best practice for dry-cleaning. If compressed air is used on food contact surfaces, you may need to consider filtration of the air at point of use.
- Refer to chapter 3, section 2 - previously in this manual for a more detailed explanation of establishing a routine cleaning program.

Packaging Materials

- Cover packaging materials that are stored in order to prevent contamination.
- Inspect and monitor packaging materials for moisture / humidity damage and presence of insects - such as psocids.
- Practice FIFO with packaging materials.

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Section 8: Bulk Vessel Sanitation

To maintain product integrity, it is important to consider the entire supply chain. Product shipped in bulk vessels such as railcars and bulk trailers needs to be included in the sanitation plan.

Bulk Trailers and Railcars
Establish a frequency for washing bulk trailers. This frequency can be established by gathering information from inspections to establish these guidelines. Seven to 28 day wash cycles are common in the industry for bulk trailers, but weather conditions and product type may dictate cycle adjustment. Railcar cleaning will typically consist of an annual wet wash with inspection and dry cleaning employed throughout the year.

With an established wash frequency, it is still imperative that bulk vessel inspection take place prior to each load. The wash frequency must be determined, but the inspection will determine if the vessel meets the sanitation requirements or may need to be washed out of cycle. The below inspection points would be employed for both rail car and bulk trailers.

Vessel inspections prior to loading should include:

- Visually inspect all hatch lids, gaskets and all stinger connections (if the vessel is so equipped) for filth, mold or moisture.
- Inspect the vessel interior, all product lines, all product hoses and hot hoses, all fittings and gaskets for same.
- Make sure blowdown line is screened to prevent pest entry.
- Look for evidence of product build up, mold growth, infestation, condensation or water intrusion into vessel.
- Make sure that gaskets are pliable to provide an effective seal and that they are clean.
- During the loading process, leave hatches open no longer than required to complete the interior inspection., Keeping this open time to a minimum will serve to reduce the opportunity for pest entry at this point. Use hose stands to prevent product hoses from touching the ground during the loading and unloading process where applicable.

Van Trailer Inspection
Van trailer inspection must be completed on incoming and outbound shipments. Inspection criteria items include, but are not limited to:

- Check structural conditions such as damaged walls, floors, and ceilings that could support infestation or leak.

- Make sure door seals are tight to prevent pest entry and leakage.
- Look for foreign material on floors, walls, and ceiling from previous loads.
- Check for odors from previous loads and from materials used to mask odors (ground coffee or grape Kool-Aid).
- Make sure locks or seals are intact for food security.

Sanitation
Establish a frequency for washing bulk trailers. This frequency can be determined by gathering information from inspections to establish these guidelines. Seven to 28 day wash cycles are common in the industry for bulk trailers, but weather conditions and product type may dictate cycle adjustment. Railcar cleaning will typically consist of an annual wet wash with inspection and dry cleaning employed throughout the year.

With an established wash frequency, it is still imperative that bulk vessel inspection take place prior to being loaded. The wash frequency must be determined, but the inspection will determine if the vessel meets the sanitation requirements or may need to be washed out of cycle.

Wash facilities should be audited to insure sanitation activities that take place and meet your internal requirements. Also, consider the possibility that your carrier may use alternate wash facilities on occasion. Are they inspecting those locations?
Items to consider include but are not limited to:

- GMPs
- Product zone behaviors
- Pest control
- Training records
- Wash procedures
- Water quality
- Chemical control
- Safety Data Sheets
- Blood-borne pathogens
- Self-auditing
- Master sanitation
- Equipment condition
- Facility physical condition
- Site security

Whether loading product from the production site or from transfer sites, the expectations are the same. Procedures such as the following must be established to ensure vessels meet sanitation standards:

- **Physical controls:** Some operations include the use of a blow through sifter as part of the process. This sifter must be on an inspection and cleaning program on a frequency that would break the insect life cycle. These sifters should be kept clean to prevent trailer infestation. Tools must be identified for food contact and non- food contact surfaces.
- **Chemical control:** Fumigation can be conducted on bulk rail cars in transit. Specific state regulations **will** determine if the individual performing the aeration task should be a certified pesticide operator or under the direction of a certified pesticide operator, as well as the appropriate certification category.

Chapter 4: IPM Application for Processes

Section 9: Customer Flour Receiving and Handling

Purpose and Scope

The purpose of this section is to ensure the sanitary condition of the flour being received and the handling systems for receiving in flour and milled products. This will help ensure that the customer will produce a safe and sanitary product. This includes, but is not limited to, eliminating dead spots, caked particles of flour (commonly known as "flour scale"), and integrating this part of the facility into the Master Cleaning/ Sanitation and Inspection Plan. This will allow the removal of old flour that may cause insect infestations and may help prevent costly unscheduled clean outs and treatments such as fumigations. Inspection must be performed monthly to interrupt the typical stored-product pest life cycle. The scope of the program includes receiving ports, bins and hoppers, filter and transfer systems, screens and sifters, suction lines, dust collection systems and pressure relief bags, and product transfer lines associated with receiving flour/ milled products.

Periodic Inspection of Sifter Tailings, Thresholds and Reporting Results

Frequent comprehensive analyses of sifters tailings is needed to allow a thorough investigation of the root cause for any unusual finding. Sifter tailings inspections should be completed per lot number, tanker or rail car received, or at the emptying of a receiving bin. This requires the use of a tracking form or tailings report and helps determine any significant trends or patterns that may exist. Relative thresholds should be established for unacceptable levels and a procedure should be in place addressing how to react to abnormal findings. Establish a standard based on average or normal findings to identify an unacceptable threshold (Upper Limit).

Insect counts may spike as small pockets of insects enter the system. In addition, the insect counts may not correlate to the most recent lot received, as bugs can remain in the system and carry over to the next lot's tailings. A relatively gradual increase in counts usually indicates a system infestation opposed to an infested load having been received.

Different facilities may have different thresholds based on equipment layout and design, interior accessibility, location control points, etc.

Out-of-Tolerance Investigation

When thresholds are established and an out-of-tolerance occurs over the Upper Limit, a thorough investigation must be performed. Some items to look at are:

- The total picture including previous load(s)
- History of previous findings at the plant, seasonality, supplier correlation
- Mold or flour chucks in tailings samples indicating sanitation issue
- Live vs. dead insects (whole insects or pieces)
- Types of insects (understanding and knowing their behavior)
- Insect life stages and/or larva (look at time/date of cleaning and cleaning effectiveness)
- Any information on previous self-inspections
- Tops of bins, filter systems, breather bags, leaks, runways to usage bins

- Mill: Recent sanitation, cleanouts, and treatments
- Carrier: Performance history, wash history, hoses, and connections

Proper Identification of Insects
When inspecting flour handling systems and inspecting sifter tailings samples, it is critical to identify insects, insect life stages, and insect parts. Properly identifying insects will tell you what type of environment you are dealing with. Many facilities will have pictures posted to get a quick ID. It is recommended to have a trained entomologist properly identify insects when needed. For more information see the Key Stored-Product Pests section of this manual.

Routine (scheduled) Sifter Inspections
Along with checking sifter tailings it is critical to ensure the sifter is operating properly. This can be accomplished through a Preventative Maintenance (PM) program or any other routine inspection program frequency. Types of sifters in operations are Centrifugal-Rotary, In-Line, Gyratory, Pressure, Convey-Through, and Portable. Some items to consider when developing a sifter inspection program include:

- Determine sifter system inspection frequency (should be 30 days or less)
- Determine the process for the sifter breakdown (manufacturer manual)
- Use 30 mesh screens or smaller
- Inspect for holes and flaws
- Inspect all connecting product lines, suction lines, and dead spots to the sifter
- Develop written sifter inspection procedures
- Develop a work form to track cleaning, maintenance, and repairs

Routine (scheduled) Flour Systems Inspections
Inspection points in the flour systems need to be determined and documented on a Master Sanitation Schedule. Some examples are:

- Bin head space (from the exterior top hatch)
- Filters and bags
- Socks
- Boots
- Manhole and inspection port gaskets
- Inline valves
- Scales
- Return lines
- Area below air slide fabrics

These inspections are to be conducted by trained and qualified persons, and all findings should be recorded on a standard form.

Routine (scheduled) Cleaning of Flour Systems
Thorough inspections will indicate if there is a need for cleaning and should be done as part of establishing cleaning frequency. When cleaning frequency and procedure is determined, only

trained and qualified persons should perform the cleaning. The training requirements for these persons may need to include confined space entry. Dedicated cleaning equipment must be established and may include pressurized air hose and wands with valves, industrial vacuum cleaners, PVC vacuum tubes, color-coded stiff bristle brushes, extension handles, and plastic scrapers. Cleaning procedures and verification of cleaning must be developed. Some items to consider in the procedures include:

- Start at the top and work down to the bottom using brushes and vacuums as much as possible; minimize the use of pressurized air
- Ensure all flour handling equipment is cleaned at the same time
- Include reclaim bins, inline valves, hoppers, sifters, and unloading equipment for rail and truck in the cleaning or inspection
- While cleaning, inspect all equipment to make sure it is functioning properly, as malfunctioning equipment often becomes infested due to poor product movement
- Document any issues found **and verify cleaning as part of pre-operational inspections**
- Determine if a treatment is needed

Bulk Receiving Inspection
A bulk receiving inspection program with a written procedure should be developed for both trailer and railcar shipments. The program must include:

- Verifying seals/ seal numbers at pre-determined seal points (hatches, vent covers, hose tube covers, etc.)
- Inspecting product hoses and product lines for cleanliness
- On trailers, looking at discharge outlets, feeder compartments, the corners of plastic sheets, gaskets, and air relief socks
- Documenting all points of inspection with each incoming shipment
- Develop reject criteria for the program and communicate these expectations with the supplier(s)

Unloading and Transfer Equipment
The bulk unloading and transfer equipment needs to be part of the receiving process, but also needs to be cleaned and inspected on a set frequency. Some items to start with are:

- All receiving ports should be capped and locked when not being used
- Hose caps must be in place to prevent pest entry when the equipment is not in use
- Properly store unused caps, hoses, gaskets, and other equipment
- Maintain flexible unloading hoses in good condition, and frequently inspect the hoses for wear on the internal lining
- Frequently clean all unloading equipment and document on the Master Sanitation Schedule

Receiving and Storage of Bagged Product
For receiving bags or totes from van trailers that will not go through your bulk system, a thorough, written bagged product receiving/ inspection program and form must be developed. Items to include are:

- During trailer or rail car receiving, inspect bagged product starting with the top layer, inspect between some of the bags and along the folds and shrink wrap.
- Inspect the pallet for activity or damage affecting the bagged product.
- If issues are found you may restack the pallet, remove affected product or reject according to an established, written procedure.
- After all pallets are pulled out, inspect the condition of the trailer or railcar.
- Develop reject criteria and document all findings on the receiving inspection form.
- As new materials are received, stage them in a designated area until final acceptance/reject determination is made.
- Document all findings on a written form; trend non-conformance issues

Integrated Pest Management
A flour receiving and handling program must be part of the facility's Sanitation and Integrated Pest Management (IPM) program. If thoughtfully laid out, the program will allow for determining root cause in a timely basis and prevent undesirable conditions. Some considerations include:

- Know that Inspection/Sanitation is the first line of defense
- Know your trouble spots - what is the plant and equipment history?
- Sanitary design – Engineer out the defects; allow access for cleaning
- Use preventive programs such as MSS, Self-Inspections, and Exclusion
- Use Leading Indicator Programs (tailings, pheromones, insect light traps, sighting logs)
- Set and follow the threshold
- Communicate with in-house and contracted pest management service
- Develop a plant-specific IPM plan, detailing key responsibilities, frequencies, monitoring, cleaning methods, physical controls, and chemical controls
- Properly identify pests
- Properly train all involved in IPM activities
- Utilize trend reporting - the more data the better
- Share best practices between employees, departments, facilities, and organizations

Summary

In summary, an IPM program for the receiving and handling of flour is of utmost importance. Several considerations must be taken into account, including periodic inspection of sifter tailings, results, thresholds and reporting, routine inspection and cleaning of flour systems, bulk receiving inspections, and moreover, standard IPM practices. A monthly inspection program will help to ensure the sanitary condition of flour handling systems for a safe and sanitary product.