PEST MANAGEMENT IN FEED MILLS

Bhadriraju Subramanyam, Ph.D.
Department of Grain Science and Industry
Kansas State University
USA

PESTS

Pests often associated with feed mills include stored-product insects and mites, cockroaches, flies, rodents, and birds. The economic losses caused by insects usually do not exceed 5-10%, but losses caused by rodents and birds can range from 5 to more than 50%. It is important to realize that pests are present both outside and inside the feed mill, and there is always constant movement of pests between the mill interior and exterior. Therefore, control tactics should be aimed at reducing both outdoor and indoor pest pressure. Pests are present in any environment because conditions conducive for them exist, and some of these conditions have been provided by our human activities through our poor sanitation and production practices. How extensively a pest is distributed in a feed mill environment is directly related to pest's accessibility to food, shelter, and moisture, and effectiveness of our pest management program. Feed mill buildings and feed mill equipment that are not designed to exclude pests and product accumulation, respectively, permit pests to proliferate in a feed mill environment. Recognizing the type of pests and their sources of infestation, and understanding their ecology (how they interact with the environment around them) are keys to successful management. This article provides a brief overview of invertebrate and vertebrate pests associated with feed mills and discuss sustainable methods for their management.

INTEGRATED PEST MANAGEMENT

The use of sampling information, assessment of cost/benefit and risk/benefit ratios, and judicious use of pesticides and alternatives for managing pests is called integrated pest management (IPM) (Hagstrum and Subramanyam 2006). The goal of IPM is not to eliminate pests or reduce use of pesticides, but to maintain pests below damaging levels using multiple approaches with favorable social and economic consequences. Also, IPM approaches rely on using pesticides only when needed, which has beneficial effects such as delaying development of pesticide resistance and extending the useful life of pesticides.

STORED=PRODUCT INSECTS

Insects enter feed mills through open doors and windows. A careful inspection of the mill exterior and interior will reveal potential entryways, and these should be sealed or closed. This may not always be possible. The use of air curtains above open doors prevents insect entry by creating positive pressure airflow near the doors. The use of plastic strips may also minimize insect entry. Broken windows should be screened with mesh screens (84 micrometer openings), and damaged mesh screens should be replaced with new ones. Bulk-stored grain or bagged grain should be inspected at the time of receipt and after storage at monthly intervals for signs and presence of insects. Measurement of grain temperatures within silos and round metal bins provides an indirect measure of insect activity, because insects can cause dry grain heating resulting in temperature increases of 42.2°C. Bulk-stored grain or pelleted feed in silos or bins

should be sampled with vacuum probe, grain trier, or deep bin cup probe to estimate absolute insect densities. If bulk or bagged grain is stored for more than a month, infestations can be monitored using perforated probe traps (www.trece.com; www.opisystems.com), a method that provides relative estimates of pest density. These traps capture randomly moving insects within the grain mass, and have a high probability of detection because they work 24 hours a day and 7 days a week, unlike absolute sampling methods. It should be borne in mind that traps are monitoring tools and not tools to remove insects from infested grain

Incoming ingredients should be inspected, including the trailer that delivered the material. Grains that are received at the mill should be inspected to determine whether they are infested. If live insects are present, the grain should be fumigated with phosphine to kill all species and stages of insects. A minimum concentration of 300 ppm for at least 100 hours is necessary to effectively kill insects. Therefore, sealing bulk and bagged materials to prevent loss of phosphine gas is important.

The use of air tight structures or cocoons (www.grainpro.com) is an excellent tool for those feed manufacturers that are organic or do not have pesticide products approved for admixing with grains. The cocoons can be used for bulk storage of grains or for bagged grains. Grain is a living entity, and once inside these air tight structures, the respiration of grain elevates carbon dioxide levels and reduces oxygen levels to below 2%. Oxygen levels below 2% are lethal to insects and mites, and also discourage other aerobic organisms. These air tight structures also come with a facility to connect to a vacuum pump to reduce oxygen levels below 2%. The use of vacuum may be suitable for finished feed, because unlike grains finished feed is not a living entity. In other models, the cocoons come with a connector that can be connected either to a carbon dioxide cylinder or to a cylinder containing either gaseous phosphine (ECO_2FUME), sulfuryl fluoride (ProFume, www.dow.com), or methyl bromide (www.chemtura.com). The flexibility offered by these cocoons is unique and should allow feed manufacturers to store grain with minimal losses due to insects. Although I have not seen any data, the cocoon manufacturer claims that the cocoons are durable (10 years) and not susceptible to damage by rodents.

If grain is to be stored for several months during warm weather, treatment with a grain protectant might be desirable, if allowed. Bagged materials should be sampled with spear samplers or scoops and the contents sifted to determine infestations. The seams of bags should be carefully inspected for insects or webbing caused by moth larvae. The dump pits and horizontal screw conveyers should be inspected for insect activity, and should be cleaned regularly to remove grain residues.

Insects within the mill can be determined through visual inspections or by use of special trapping devices (www.trece.com). There are several manufacturers that make sticky traps or traps with food and pheromone lures that are attractive to a range of stored-product insects. The traps for crawling insects should be placed on the floor in areas where they are not disturbed. The traps come with a dust cover to exclude dust. A minimum of 30 traps in different areas of the mill is a good starting point. These traps should be checked biweekly or weekly and the types and numbers of insects captured should be enumerated. There are sticky traps with lures for flying insects, especially some species of beetles and all moths associated with stored products. These traps should be hung at eye level for easy inspection. It is important to remember that absence of insects in traps does not indicate that the mill is free of insects! Whether or not a trap captures an insect is based on insect behavior and environmental (temperature, humidity, light, sexual maturity, etc) conditions that trigger insect movement.

Sanitation, both outside and inside silos, bins, and feed manufacturing plants (including floors and equipment), is the most important IPM technique (Imholte and Imhote-Tauscher 1999, Subramanyam *et al.* 2005). The grounds and mill perimeter should be devoid of any vegetation and food product spills, and should be paved. This eliminates harborages and creates an unfavorable environment for pests. The roof should be inspected regularly for proper drainage and for any accumulations of product, which may have leaked from bucket elevators, cyclones, exhausts, or other equipment positioned on, or passing through, the plant roof. Leaking equipment should be repaired and product accumulations removed. Storage facilities receiving grain should be thoroughly cleaned and treated with an approved pesticide to control residual insect populations to prevent contamination of insect-free grain loaded into the facility. Several diatomaceous earth formulations or cyfluthrin (Tempo), a synthetic pyrethroid, are recommended for treatment of empty storage facilities. It is important to check with your pest management professional or a regulatory authority regarding suitable products for application to empty grain stores. The products should leave residue to control infestations for at least 10 weeks or more, and make sure that insects have not developed resistance to the applied product.

It is virtually mandatory to have an effective dust control system on the receiving and handling systems. Proper dust control prevents dust from becoming a housekeeping problem, and reduces cleaning costs. Even with a good dust control system, some spillage will occur. Therefore, regularly scheduled cleaning is important in the receiving, handling, and storage areas. Cleaning frequency should be based on the observed need, and may vary depending on the intensity of operations. As a general rule of thumb, walls, overhead areas, and equipment interiors should be cleaned at least once each month to prevent insect development. Dead spots in handling equipment can become breeding areas for insects unless they are cleaned monthly to break the insect developmental cycle.

Increased emphasis on cleaning and the use of insecticide sprays, fogs and/or mists in plant spaces has been used to supplement general fumigations as an alternative to spot fumigations. There are several pesticides that can be used inside a plant for spot, crack or crevice, or for general surface treatments. Sanitation enhances effectiveness of these pesticides. General fumigation (with methyl bromide) requires proper sealing of the entire plant structure so that the toxic gas vapors can be held at lethal concentrations to provide effective insect kill. Sulfuryl fluoride is a viable alternative to methyl bromide, and is currently registered for use in feed mills. An effective alternative to fumigation is the use of heat treatment for disinfestation of the entire plant or specific plant areas. Gas, electric, or steam heaters can be used to supply the necessary heat. During heat treatment, the temperature of the feed manufacturing plant should be raised to at least 50°C and held at this temperature for 24-36 hours. A successful heat treatment is one in which uniform temperatures of 50-60°C are attained in all parts of the plant, including equipment. This is usually accomplished by proper distribution of heat using strategically placed fans. Furthermore, sanitation and removal of grain and grain products from the plant enhances heat treatment effectiveness, because grain and grain products are poor conductors of heat. Issues with sanitation and infestation within pieces of equipment can be easily identified during a heat treatment, because insects tend to spew out of equipment as it gets hotter. Both fumigation and heat treatment are responsive tactics and lack residual effectiveness and insect reinfestation following these tactics is a possibility.

Finished feed products may be stored and transported in bulk or bags. Bulk storage is commonly used for finished feed products prior to bulk load-out or packaging for bag shipment.

Particular care needs to be exercised to assure that these products are not infested or contaminated in storage. Encrusting of material or mold build-up in bins is an indication of condensation or of a high humidity problem in the bin. This problem may be corrected by increased suction on the bin to carry off warm, moist air. Physical cleaning of the bin usually requires lowering properly protected workers into the bin to scrape down bin top and wall areas. If packaged materials are to be warehoused, they should be neatly stacked on pallets and stored in organized units at least 60 cm from walls and upright supports. This arrangement provides minimum space for cleaning along wall areas, facilitates inspection and inventory of the warehoused material, and allows for the placement, maintenance, and inspection of traps.

COCKROACHES, FLIES, AND MITES

Cockroaches and mites are associated with feed mills, especially in hot, humid tropical climates. Cockroaches prefer warm, moist areas and are omnivores. Cockroaches feed on a variety of filthy material and are carriers of many pathogens. Multiple tactics should be used for cockroach management. The use of traps for monitoring populations and identifying problematic areas is the key. The use of baits to reduce the amount of insecticide introduced into an environment is a novel approach. Application of insecticides may be needed at high population densities. Heat treatment has been shown to eliminate the sources of cockroaches and drastically reduced the need for repeated chemical application.

Flies are common where there is filth and moisture. Like cockroaches, flies carry many pathogens. Management of flies requires that the grounds are well drained of water and kept in good repair. There are several toxic and non-toxic baits for flies. The use of light traps (passive) is generally a preferred method but the light traps should be used away from production areas. Exclusion tactics such as closing doors, windows, or use of air curtains above doors or plastic strips should discourage flies from entering a facility.

Mites are eight legged creatures, and several species of mites are associated with feed mills and feed materials. Mites thrive under humid conditions (80-90% humidity), and can develop at temperatures as low as 9°C, whereas stored-product insects generally fail to develop at temperatures below 15°C. Egg-to-adult development of mites takes 2-3 weeks whereas that of stored-product insects takes 30-40 days at optimum conditions (28-32°C). The best method to manage mites may include the use of cocoons, application of residual products, fumigation, or managing moisture in the feed mill. Modified atmospheres (low oxygen atmospheres by use of carbon dioxide or nitrogen) also offers a solution for mite infestation in packaged and tightly sealed packaged feed products.

RODENTS

There are native rodent species and species that are associated with human or agricultural habitats. In general, only 10-15 species out of the more than 1700 rodent species are pests, and these rodents are generally called as commensal ("sharing the same table") rodents because of their close association with humans. Rodents damage grain crops and grain in the field and losses contributed by rodents to crops is significant. It has been estimated that nearly 280 million undernourished people can benefit if damage by rodents to field crops can be prevented (Meerburg *et al.* 2009).

Effective rodent management requires the use of several techniques (Singleton and Petch 1995,

Corrigan 2001, Meerburg *et al.* 2004). The key is to first hire a pest management professional, who can conduct a thorough inspection of your facility to determine the best strategy. Exclusion techniques or rodent proofing the building is the key to a successful rodent management program. Although total exclusion might not be possible due to the size or design of a facility, every effort must be directed to identify possible route whereby rodents can enter the building. Openings greater than 0.64 cm for mouse and 1.27 cm for rats must be sealed. Hardware cloth, coarse steel wool, or mortar can be used for sealing purposes. A 30.48 cm metal plate should be attached to the outside of doors. Rodents should be prevented from climbing pipes outside the buildings by fitting metal guards around the pipes. The ultimate aim is to exclude rodents from entering the facility.

All animals need food, shelter and harborage to survive. Removing any one of these factors will have an impact on the rodent populations. Therefore, proper sanitation is essential. This includes removal of trash and garbage piles, removal of grass, weeds and undesirable vegetation adjacent to buildings and elimination of potential rodent harborages. Proper storage practices that will permit regular cleaning and inspection are also important. It is necessary to practice good housekeeping that will limit areas where rodents can nest. Products should be placed on pallets, away from walls, so as to allow inspections, cleaning, and appropriate rodent management measures.

Another important method of rodent management involves the use of traps and rodenticides. The home range for a rat is about 30 m and that for a mouse is about 3 m. This behavior should be taken into consideration when placing traps and bait stations. Traps and bait stations have to be placed every 2.4-3.6 m for mice and 7.5–15.0 m for rats. Trapping is one of the safest methods for managing rodents, because it does not involve the use of toxic materials. Traps are useful in areas where poisoned baits cannot be used, especially inside the plant. Also, dead animals can be easily located and discarded. To be most effective traps should be placed along normal runways with the triggers of spring traps placed adjacent to walls. Traps also need to be checked more frequently. The most commonly used traps are snap traps. These are usually baited with peanut butter, although there are newer models with expanded triggers that do not require baiting. Glue boards or sticky traps can also be used in the same manner as snap traps. However, rats are more difficult to catch on glue boards, because they are larger and stronger than mice. Automatic multiple catch traps or "Ketch-alls" are used to catch mice. There are two types of multiple catch traps-one uses a wind up mechanism that throws the mice into a chamber, and the other uses a trap door principle.

Rodenticides can be classified into two main groups-anticoagulants and non-anticoagulants. Anticoagulant rodenticides cause rodents to die of internal bleeding. The poison disrupts the blood clotting mechanism of the animal. All anticoagulants are slow acting, and death may occur from 3-10 days after bait consumption. The older anticoagulant rodenticides required multiple feeding by rodents, whereas the newer ones require a single feeding. Non-anticoagulant rodenticides cause death of rodents in various ways. Most of the non-anticoagulants are single dose poisons.

Bait shyness and resistance to rodenticides may sometimes be encountered. Baits must be fresh and attractive to the target rodents. Prebaiting with a non-toxic food source may sometimes be necessary to overcome bait shyness, and also to monitor rodent activity. However, all other competing food sources must be eliminated. Liquid baits may prove more effective in managing rodent populations in areas where water is a limiting factor. Tracking powders (rodenticides in

powder form) are often used when baits are not well accepted or where food is abundant. These are usually blown into rodent burrows or wall voids. The rodents pick up the dust and ingest the toxicant while grooming themselves. Fumigation of rodent burrows is an effective rodent management method. However, only licensed and trained professionals or applicators should carry out fumigation of rodent burrows.

Three lines of defense are critical in any rodent management program. The first line is at the perimeter or fence of the facility to intercept rodents entering a facility from an outside harborage. Harborages such as tall weeds and other vegetation should be removed. Tamper-resistant bait stations should be placed at regular intervals along the fence. The second line of defense is around the building perimeter, and bait stations should be placed at regular intervals. In addition, woodpiles, empty boxes, logs, etc., near the building perimeter should be removed. Lawns should be mowed. Thick shrubs and ivy and vine growth on the walls should be removed. Trees and shrubs should be pruned. All water leaks should be fixed to reduce a source of water. Trashcans and dumpsters should be provided with tight lids and kept away from the building. The third line of defense begins with the building interior. All potential entry points like doors, vents, and pipes have to be sealed to exclude rodents.

BIRDS

An integrated pest management plan is necessary to tackle a bird problem. There are five basic approaches in managing a bird population. These include survey, sanitation, exclusion and habitat alteration, repellents, and population reduction. Surveys are necessary to identify the bird species and to study their activity patterns. Sanitation involves limiting or reducing access to food, water and shelter, in addition to regular removal of nests. Frequent clean up of spilled grain outside feed manufacturing plants is difficult and impractical. However, an effort should be made to change practices that cause grain spillage. Cleaning clogged drains, leaks, and standing water on roofs will help remove a water source. Persistent destruction of nests will greatly reduce populations of sparrows and pigeons.

The aim of exclusion is to deny access to enter or use the building as a nesting, roosting or loafing site (Henderson and Lee 1992). Plastic bird nets, covers, or ramps can be used to keep birds out of certain areas. The way a building is designed will provide harborage for large populations of birds. Therefore, building modifications play an important role in bird management. Various kinds of repellents are available that can either scare the birds away or make it difficult for them to use the building as a nesting or roosting site. Different wires, such as porcupine wires, bird barrier coils, spikes, electrically charged wires, and piano string have been used to physically prevent birds from nesting and roosting. Sticky substances have been used, in certain situations, to repel birds.

Population reduction is mainly achieved by the use of toxic baits, traps, and sometimes, by shooting. Toxic baits have to be used with caution, as they may prove hazardous to non-target domestic animals or wildlife. Avitrol and Starlicide are two commonly used baits for pigeons and starlings. Prebaiting with untreated grain will improve the efficacy of toxic baits. Pigeons and sparrows can sometimes be trapped near their loafing or feeding sites. Traps should be placed in the shade, and food and water should be provided. Leaving a few birds in the trap will serve as a decoy to lure more birds. Shooting is possible where relatively few birds are present. However, large-scale shooting programs should not be carried out because of safety reasons, and due to the possibility of bad publicity.

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